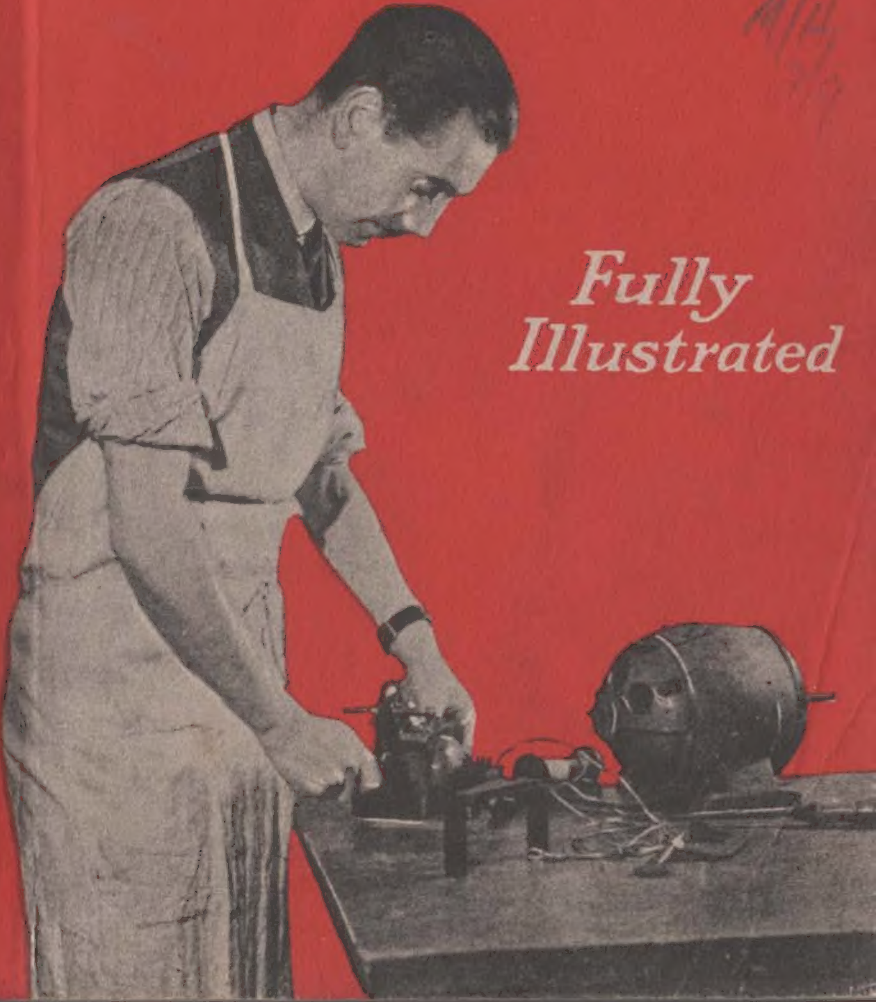
The "Amateur Mechanic & Work" Handbooks

SMALL DYNAMOS AND HOW TO MAKE THEM



Fully Illustrated

SMALL DYNAMOS

AND HOW TO MAKE THEM

Practical Instructions on building a variety of machines including electric motors

WRITTEN BY EXPERTS

WITH 132 ILLUSTRATIONS

CASSELL AND COMPANY, LTD
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EDITOR'S PREFACE

This handbook gives clear, explicit and eminently practical instructions for building a useful selection of quite small dynamos and fractional horse-power motors.

The authors who have contributed most of the information are: A. H. Avery, A.M.I.E.E., Henry Greenly, A.I.Loco:E., and Edward W. Hobbs, M.S.M.E.E.

Particular attention is directed to Chapter II, which explains how to make small machines without expensive tools; the motor described is very serviceable for No. O gauge locomotives and small-power work generally.

Chapter VI, dealing with the subject of ways and means of driving a dynamo, is helpful and contains a concise résumé of many practicable methods.

Readers requiring information on larger types of machines should consult the companion handbook, "Dynamo and Electric-motor Building" by A. H. Avery.

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SMALL DYNAMOS
AND HOW TO MAKE THEM

CHAPTER I

How a Dynamo Works: General Considerations

As the machines described here are of the smallest size compatible with their being of practical use, it may be assumed, in the case of many readers interested in this book, that probably the building of one of these machines will represent their initial attempt at dynamo or motor construction, and that they will be without the little elementary knowledge of the subject which would so greatly facilitate the work and also render it more interesting. For these reasons this chapter has been devoted to the elementary theoretical principles of the dynamo, together with a few generalities of construction.

Since the time of the earliest electrical research it has been assumed that electricity flows in a conductor circuit much in the same way that water flows in a pipe, and also that the flow, relative to its source, is in a certain direction. These assumptions should not be taken as literal facts, for they are of a purely hypothetical nature, and have only survived because they lend themselves so readily to the practical application of the known laws of electricity. In the

construction of a dynamo or motor the presumed directional flow of electricity is of great importance.

The Simple Dynamo.—In Fig. 1 is shown diagrammatically a simple dynamo. Its action depends, as does that of any other dynamo, on the fact that when a conductor circuit is caused to cut lines of magnetic force, electric currents are set up in the circuit. In simpler language, all magnets appear to be surrounded by some mysterious force which has the power of attracting iron and steel; this invisible area of force is termed the magnetic field, and it is when a closed conductor is moved across this field that an electric current is induced in it.

Conversely, if a conductor carrying an electric current is placed in a magnetic field it will tend to move so that its own field coincides with that in which it is placed; thus we get the electric motor.

Returning to the consideration of the dynamo, it is obvious that, for one revolution of the loop of wire, one side of the rectangle will cut the magnetic field twice, once at the north pole and again at the south pole, and as the direction of flow of an induced current depends upon the direction of magnetic-flux and the direction of motion of the conductor, two currents of opposite direction will at different times flow in the circuit. Expressed in a more simple manner, a conductor, when passing the north pole, would have a current induced in it of opposite direction of flow to that which it would have when passing the south pole.

No mention has been made of the collection of the current for use in a circuit exterior to the dynamo. It

is evident that if merely simple rubbing contacts were made—one for each end of the rectangle of wire—the current obtained would be of an alternating nature, flowing first in one direction and then in the other, and that if a unidirectional (the "direct") current is required, some means must be provided for commuting this alternating current. To do this the connections of

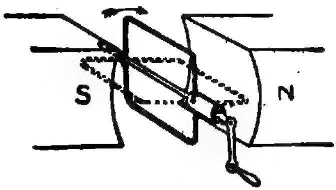


Fig. 1.—A Simple Dynamo

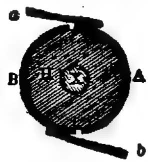


Fig. 2.—Two-part Commutator

the two ends of the loop must be continually changed over.

This is accomplished mechanically by means of a commutator, shown in Fig. 2. In its simplest form it consists of a metal ring split longitudinally so as to form two segments, A and B, these segments being mounted upon a bush of insulating material, H, the whole being supported upon the axle X, which carries the rectangle of wire. One end of the loop is connected to one segment and the other end to the other segment. The current is collected by means of two brushes, *a* and *b*, situated diametrically opposite each other. The action of the commutator will be readily understood. As the wire loop, and with it the commutator, is revolved, the two segments alternately come

into contact with each brush. The relative positions of loop, commutator segments, and brushes are such that the change is made just when the current is about to reverse.

The simple dynamo just described is of academic interest only, for the current obtained from it would require sensitive instruments to detect; its design, however, is fundamental of that of the present-day practical dynamo.

It has been shown that for the production of an alternating current there are two essentials in a dynamo, viz.: the field-magnets and armature—the latter being represented by the loop of wire in the case of the simple dynamo just considered—and that current is produced when the armature is caused to revolve (there are variations of this arrangement, but these do not concern us here).

The usual method of collecting the current is by means of spring brushes pressing upon insulated rings mounted upon the armature shaft.

In the case of the direct-current dynamo the essentials consist of field-magnets, armature and commutator. Figs. 3 and 4 show typical dynamos.

Field-magnets.—A dynamo may be built with permanent field-magnets or with electro-magnets. On certain types of small machines, which are described later, permanent magnets are very useful as is explained in the chapter dealing with that type of dynamo, but for the construction of a really efficient dynamo electro-magnets are a necessity. The usual shape of the permanent magnets is the horseshoe.

The design of electro field-magnets has taken a great variety of forms in the past, but now it has settled into a few standard patterns which theory and practice have proved to be the most efficient. These are shown in Figs. 5 to 10. Each has its special merits

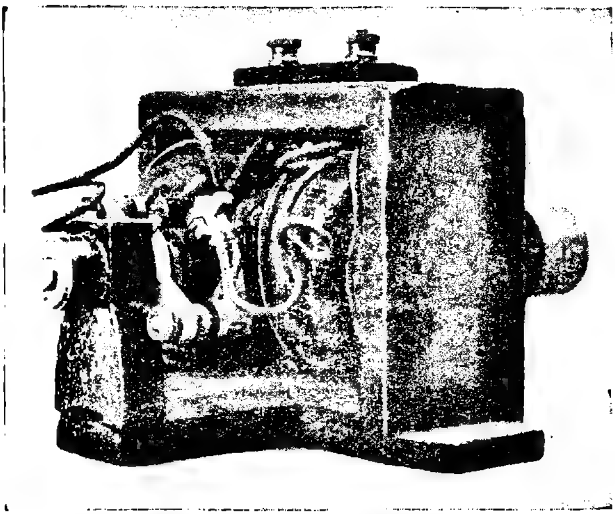
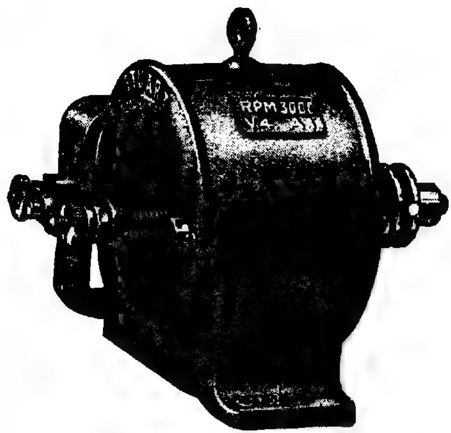


Fig. 3.—Typical Small Dynamo

either from a point of view of efficiency or of simplicity of construction combined with a fair percentage of efficiency. Undoubtedly the type shown in Fig. 5 is the most efficient all round, and also is the design embodied in practically all commercial machines of the present day. The ironclad type, Fig. 6, comes next in the matter of efficiency, whilst the merits of the others are about equal In all these last a certain

amount of efficiency is sacrificed for the sake of simplicity and ease of construction.

In some cases field-magnets are built up of two or more parts on account of simplified construction and winding. When this is done it is of vital necessity that the joints should be a very good fit; in small



By courtesy of Stuart Turner, Ltd.

Fig. 4.—The "Stuart" Dynamo

machines magnets should be all in one piece if possible. The field-magnets of small machines are usually of cast iron, though wrought iron and cast steel may also be used. From a magnetic point of view wrought iron is slightly superior to cast iron, but against this must be set the greater difficulty of working.

Armatures.—The armature of the practical dynamo differs considerably from that of the simple dynamo

previously studied; the difference, however, is of design and not of principle. In place of the single rectangle of wire it is necessary to have a number of conductors; also, as these conductors have to be rotated at a high rate of speed, they must be well supported mechanically. The core of the armature provides the necessary mechanical support and at the same time provides a

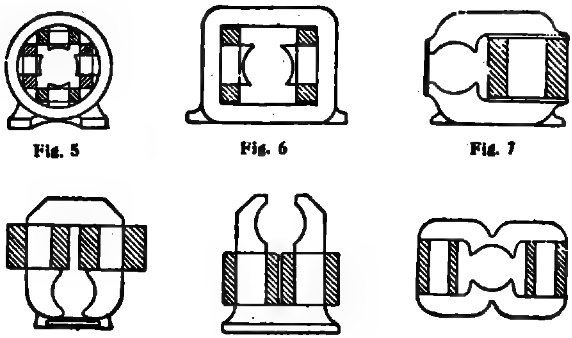


Fig. 5 Fig. 6 Fig. 7

Fig. 8 Fig. 9 Fig. 10

Figs. 5 to 10.—Types of Field-magnets

path for the lines of magnetic force, concentrating them in the region that is cut by the conductors. The core thus serves a mechanical and also an electrical purpose.

In the smallest machines armatures are sometimes made of solid iron, but in larger machines—or, indeed, in any machines in which efficiency is a consideration—armatures should be built up of thin charcoal-iron stampings. If a solid iron armature is used it should

be made of very soft iron in order that the magneti changes may the more easily take place. Solid iroı armatures have a great tendency to get hot, the heat ing being due to eddy currents which are set up in th iron; in the built-up, or laminated, armatures, as the are termed, these eddy currents are prevented to great extent.

The variety of patterns of armatures is almost a diverse as that of field-magnets, although, broadly those in general use may be divided into three types the shuttle, or H, armature; the ring; and the drum— and it is the drum that is used almost exclusively a the present day as being the most efficient electrically and, in addition, if the H armature, which is only usec for the smallest dynamos, be excepted, the easiest tc wind.

In the simplest types of small dynamos the H armature is used to a very considerable extent, anc although it has many faults, its simplicity is greatly in its favour. An armature of this type is shown ir Fig. 11. It is the only type of armature which is used in a solid form, and it would be folly to use it at all in any but the smallest dynamos. The current generated by an H armature dynamo is of a fluctuating nature, rising to a maximum at every half revolution ol the armature. Such a dynamo is useless for the purpose of charging accumulators, because at every half revo- lution of the armature the brushes are momentarily short-circuited through the commutator segments, and this would naturally discharge the accumulator as fast as any charge was put into it. The current from

H armature dynamo is suitable for very small lighting systems, and when used for this purpose there is no necessity for a commutator, for the alternating nature of the current is of no consequence.

The tri-polar armature (Fig. 12) is a slight improvement upon the H armature inasmuch as the brushes are not short-circuited at every half revolution, and also when used for motors it is self-starting, there being no dead point.

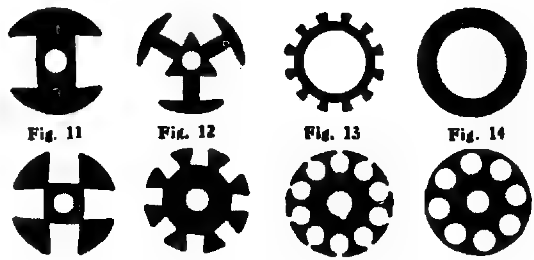


Fig. 11 Fig. 12 Fig. 13 Fig. 14

Fig. 15 Fig. 16 Fig. 17 Fig. 18

Figs. 11 to 18.—Types of Armatures

The next type of armature is the ring type and this in the past has been used to a considerable extent. The inherent bad features of this type are the fact that it carries a lot of wire which is not producing current, and also the trouble of winding and of effecting repairs in the case of a fault. As the output of a dynamo depends (with other considerations) on the number of conductors cutting the magnetic field, and as, in the case of the ring armature, only the conductors which lie on the outside of the ring cut the field, those which

pass inside and over the ends are so much dead wire offering resistance to the current.

Ring armatures vary considerably with regard to the number of slots and are, in fact, sometimes used quite plain. Fig. 13 shows a toothed ring armature and Fig. 14 a plain ring armature.

The most efficient type of armature used is the drum, though certain defects are apparent in this which are impossible to avoid. For instance, there is a large amount of wire passing over the ends of the drum which, whilst being necessary, is not actually producing current; also it is more liable to get hot than the ring-type armature which is better ventilated. The drum armature is made in a great variety of forms, for in addition to the various numbers of slots there is variety in the shape of the slots. The simplest is the four slot (Fig. 15), and next comes the six slot, and so on up to thirty-two, which is about the maximum for small machines. Fig. 16 shows an eight slot cogged-drum armature. The slot form is usually termed the cogged-drum type. Another two patterns are the hole (Fig. 17) and tunnel (Fig. 18), the difference between the two being that in the case of the tunnel the hole is closed all round, which detail, though it has many advantages magnetically, makes the winding of these armatures somewhat difficult.

Lastly there is the plain drum, which is not a suitable form for small machines, one objection being the difficulty of keeping the air gap between field-magnets and armature sufficiently small.

A few general remarks may now be made on constructional matters.

Constructional Matters.—It will be readily understood that the greater the number of slots in the armature core (assuming that a cogged drum or ring are used) the steadier will be the current; the efficiency of the dynamo also is increased, but it must be borne in mind that with increase in the number of slots

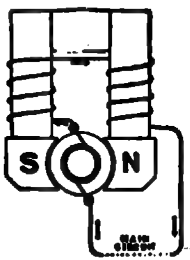


Fig. 19.—Diagram of Series Dynamo

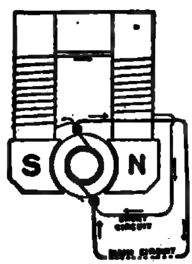


Fig. 20.—Diagram of Shunt Dynamo

there is increased complication of construction, both in the matter of winding and the making up of the commutator. For small machines eight or twelve slots are very suitable. It is not essential that the core discs when mounted upon the armature shaft should be insulated from each other, though it is generally recognised that some slight insulation such as a coat of varnish is an improvement; care, however, should be taken that the insulation of the entire core occupies only a negligible space. Core discs average about

forty-eight to the inch. A matter which is of very great importance is the insulation of the exterior of the core before the wire is put on, and very careful attention should be paid to this detail, the instructions pertaining to any particular machine being carefully carried out.

Commutators. — The construction of the commutators described in this book is quite simple, provided that the segments are not very numerous. Copper is the most suitable metal to use for commutators owing to its high conductivity, and mica should be used as insulation between each segment. It is necessary that a commutator should run true, otherwise sparking will result. Another matter to ensure is that the segments are well insulated from each other and also from the armature shaft.

Brushes. —For small machines brushes are best made of copper gauze, carbon brushes having too high a resistance for low voltages. The area of contact of the brushes on the commutator should be fairly large.

Winding.—Continuous-current dynamos are wound in three ways: series, shunt, and compound. For small dynamos and motors, such as are described in the following pages, only the two first named are used. The windings of a series dynamo are shown in Fig. 19. It will be seen that the same amount of current flows through the armature as through the field windings, and therefore if the current varies the strength of the fields will vary also. A series dynamo will not excite until the outer circuit is closed, also series-wound machines are not suitable for charging

accumulators owing to the liability of the current generated to reverse.

The shunt-wound machine is much more useful all round. Reference to Fig. 20 will show that a portion only of the armature current is shunted off round the fields, which are thus maintained at a fairly constant strength, whilst the current in the outer circuit varies according to what it is called upon to do, so that if the dynamo is driven at a constant speed the terminal voltage is practically constant. The shunt machine will excite with an open outer circuit, but there is a critical resistance of the outer circuit, below which the fields will not excite, as the armature then is practically short-circuited.

Dynamo or Motor.—In the foregoing remarks no specific mention has been made relative to design of the motor as distinct from the dynamo, and it may be wondered wherein the distinction lies: in other words, is a dynamo suitable for running as a motor and vice versa?

Briefly, all dynamos will run as motors, and many motors as dynamos, though as usually each machine is designed for its certain purpose, it by no means follows that they are working with their proper degree of efficiency in their changed capacities.

CHAPTER II

Simple Motor or Dynamo built without a Lathe

PROVIDING care is taken in regard to details, it quite practicable to make a small dynamo or mot which will work very well, entirely without a lathe any expensive tools. An example of this kind is th electric motor shown in Fig. 21, which was built u entirely by hand; the principal tools used being a fe files, a small hand-brace and drills and a hack-saw.

The general arrangements of the motor are show in Fig. 22, with dimensions rendering it suitable fo use in an "O" gauge locomotive, or as a boat moto for hulls up to about 24 inches in length.

Fundamentally, the principle adopted in the de sign and construction of any such machine is the us of "laminations," that is, pieces of thin sheet iron o tinplate cut to shape and riveted or bolted togethe to form the field magnet poles, the armature, and th frame members.

Soft sheet iron or ordinary tinplate does quit well and supplies can generally be found in the scra box or be obtained by flattening an unwanted tin box

The best way to proceed is first to make a set o laminations for the pole pieces, for which purpos about twenty-four pieces each shaped as in Fig. 2 are required. To make them, first cut out a singl piece and file it very carefully to exact size an

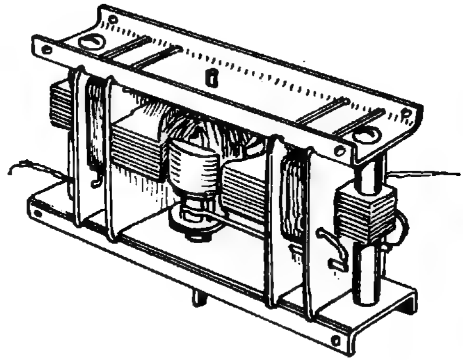


Fig. 21.—Finished Motor

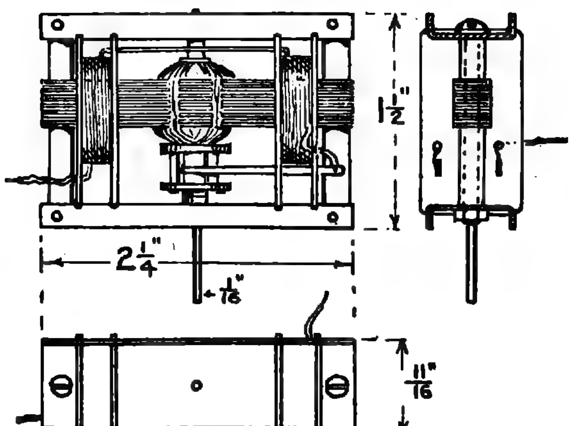


Fig. 22.—General arrangement of Motor or Dynamo

shape, then use it as a template for marking off the remaining pieces.

The surface of the tinplate can be painted with spirit black as this will make the scriber lines show up clearly. Next, cut the tinplate to shape with tinman's snips or with a large pair of old scissors, drill the hole through the narrow end, lay twelve pieces one on top of the other, bolt them together and proceed to file the whole set at once to exact size. Do

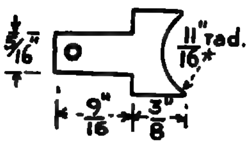


Fig. 23.—Pole Piece

Fig. 25.—Armature Piece

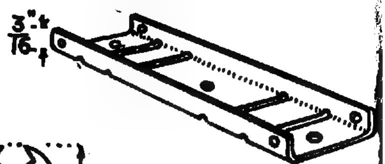


Fig. 24.—Top and bottom Frames

the same with the other set of pieces, then separate them and remove all burrs and roughnesses at the edges and flatten the pieces as much as possible by hammering them on a flat surface such as an upturned old-fashioned flat iron.

Next make the top and bottom frame pieces, shown in Fig. 24; both are alike and are made by bending up the edges of two pieces of tinplate, drilling the holes as shown, and filing the four cross slots in each. Four tubular bushes should next be made by cutting suitable lengths from a piece of $\frac{3}{16}$ in. diameter tube, or they can be made from tinplate by coiling

short lengths around a piece of ⅛ in. diameter rod. Put the two sets of pole pieces together and clamp them in position between the top and bottom frames, adjusting them and the bushes so that everything is firm and true, also that the centre holes in the frame pieces are in line with each other and that a 3/32 in. diameter steel shaft when put through them is at right angles to the pole pieces. The pole pieces may show a tendency to spring open at this stage, but it is of no importance as they will be firmly held when the four insulating distance pieces have been made and fitted.

The armature is made up in a similar way by cutting twelve discs of tinplate to roughly ¾ in. diameter and drilling a hole a bare 3/32 in. diameter in the centre of each. The exact shape and sizes of the finished armature lamination is shown in Fig. 25 and the next proceeding is to file the pieces of tinplate to these sizes. The openings between the armature poles can be drilled and cut out with snips, or can be filed away as desired; in practice there is but little saving of time in drilling, it is almost as quick and easy to file away all the unwanted metal.

One of the most difficult parts of the work is to file the rim of the discs so that they will be reasonably circular. A method that has proved to be quite practicable is to prepare a very simple filing jig—as shown in Fig. 26—consisting of a block of wood with a 3/32 in. diameter pin fixed in it exactly 5/16 in. from the top edge of the wood. The disc is then placed on the pin, and the projecting edge of the disc filed off flush with the wood, the disc is then turned about a quarter of a revolution and the edge again filed, these opera-

tions being repeated until the rim is practically dead true. The whole of the twelve pieces having been similarly prepared and made as true as possible and all burrs and roughness removed, the whole is mounted on a piece of $\frac{3}{32}$ in. diameter steel rod. They should be a tight driving fit and will need no other fixing.

The commutator is the most "fiddly" part to make, but otherwise presents no difficulties; it consists of two small discs of fibre or ebonite, about $\frac{3}{8}$ in.

Fig. 26.—How Armature Piece is shaped

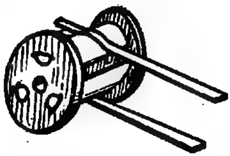


Fig. 27.—Commutator and brushes

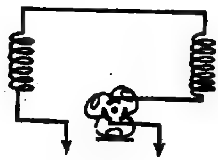


Fig. 28.—Circuit diagram

diameter and $\frac{1}{16}$ in. thick. Each has a $\frac{3}{32}$ in. diameter hole in the centre, and near the rim three equidistant holes about $\frac{1}{16}$ in. diameter should be drilled. Three small thin pieces of copper or brass measuring $\frac{1}{16}$ in. wide and about $\frac{3}{8}$ in. long are prepared by filing each end to leave a projection or tongue in the middle—as shown in Fig. 27; these tongues are then put through the holes in the little discs and the ends turned over, thus binding the whole together. Take care that these ends do not touch each other nor must they touch the shaft; all three must be quite separate.

The armature must next be wound with a fine gauge enamelled copper wire, something about 36 to 40 gauge will be suitable. Before winding on the wire, the edges of the armature pieces at each end should be filed and rounded off, then a single piece of thin silk or cotton should be wound around each of the armature poles and fixed with shellac or seccotine. The purpose is to insulate the fine wire from the metal of the pole pieces and prevent it chafing the insulation.

Next, wind each pole with the same number of turns of wire, all wound in the same direction. It is immaterial how many turns are made, the main thing is to wind each pole equally and entirely to fill the available space.

This done, scrape off the insulation from the ends of the windings and connect them as follows: starting end of first coil to finishing end of third coil; finishing end of first coil to starting end of second coil; finishing end of second coil to starting end of third coil. Set the commutator so that the slots come opposite the poles on the armature, then solder the pairs of wires to the respective segments on the commutator.

The field magnet windings should next be dealt with and may be wound with similar wire to that used for the armature, or a slightly thicker wire can be used. The end pieces which compose the bobbin ends should be cut from sheet fibre or ebonite about $\frac{1}{16}$ in. thick, but in its absence a good stout piece of cardboard can be employed provided it is varnished with shellac.

The top and bottom ends of these pieces should fit into the slots cut in the top and bottom frame members; rectangular holes must be cut in them so

that they will slip over the pole ends. Next, cove the metal between the bobbin ends with paper o silk secured with shellac or seccotine; then when dry wind each bobbin as full as possible with the insulate wire, but put the same number of turns on each an wind them both in the same direction.

Put the complete armature in place, which can b done by temporarily removing the bottom frame member, see that the armature can turn freely between the field magnet poles; if necessary file of any part of the armature poles or field magnet poles that may touch.

Drill two very small holes through the magnet bobbin pieces, in line with the commutator and fix spring copper wires in them to act as brushes. Adjust them so that they bear lightly but firmly on the commutator, then solder the starting end of one field magnet wire to one of the brushes; connect the finishing end of the same winding to the starting end of the other field magnet winding; finally solder the finishing end of that winding to the frame. This circuit is shown in Fig. 28.

By applying 4 to 6 volts plus (+) to the free brush, and connecting the negative lead from the battery to the motor frame, the machine will start up and run well.

Incidentally, this machine will run well on 6 to 8 volts A.C. owing to the use of laminations for both the field magnets and the armature.

Ready-made laminations of many kindscan be had cheaply from electrical firms; their use saves much time and labour, but unfortunately these stampings are generally only to be had for motors or dynamos of rather larger size to that described in this chapter.

CHAPTER III

Improved Cycle-lighting Dynamo

THE cycle-lighting dynamo shown in Fig. 29 is of more normal construction than those in Chapter II, and though more work is entailed in the making of it the results will well repay the extra trouble.

In designing this machine the object throughout has been to keep it simple, substantial, and dustproof. Owing to its unavoidably exposed position to weather and dust the latter is a distinctly necessary attribute of any cycle dynamo.

Fig. 29 is an outline sketch of the machine as it appears when finished. It is a very simple machine; but those who intend building it themselves are cautioned that it is useless to undertake the construction without a proper lathe and some experience of mechanical fitting.

Since alternating current gives just as good results for lighting lamps as direct current, and enables the complication of commutators and brush-gear to be dispensed with, the machine has been designed as a simple alternator with a shuttle-type armature, current being collected from any part of the framework and the insulated button contact on one end of the

armature shaft. The detail drawings accompanying this are half full size.

The vital part of any magneto-dynamo is the field-magnet. Unless this is highly magnetised and of a suitable quality of steel the results will be disappointing, and for this reason the amateur is advised to purchase his magnet ready made and magnetised, and to treat it with all possible care while building the

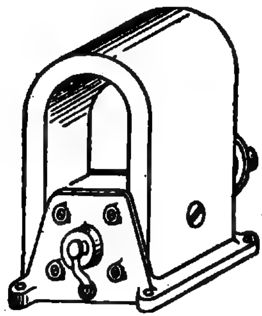


Fig. 29.—Improved Cycle-lighting Dynamo

rest of the machine. This advice applies most particularly to such precautions as keeping the magnet poles bridged across by a substantial iron armature when not in use. Dropping or jarring a magnet, too, is harmful and tends to weaken it.

Ordinary cast steel does not make good magnets, and an alloy known as tungsten steel is mostly used, as not only does this take up a higher degree of strength, but it retains its magnetism for a longer period. This steel is difficult to forge and to drill, and the least expensive way for those unaccustomed to its peculiarities is to buy the magnet complete, as

even if they succeed in shaping it up successfully, there is still the difficulty of giving it a proper degree of hardness which ensures its retentivity of magnetic properties. Fig. 30 gives the outline of the magnet in side and end elevation.

As in all dynamos, it is necessary that the armature runs as closely to the magnet as possible, and requires "pole-pieces" fitted to the magnet ends, as shown in

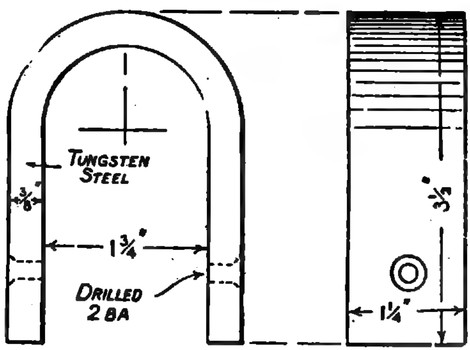


Fig. 30.—Steel Magnet

Fig. 31. These need not be of magnet steel, and they are usually made of ordinary soft cast iron, since they acquire magnetism from the proximity to the permanent-magnet poles, and lead the magnetic field into the armature where it is needed. The iron castings forming the pole-pieces are shaped or faced on the flat sides until they bed nicely against the magnet limbs, and then attached to them by means of countersunk steel screws tapped into the pole-pieces as shown.

Fix the magnet and pole-pieces on a faceplate in the lathe, keeping the magnet poles bridged across the

ends with an iron armature, and proceed carefully to bore out the armature tunnel to a diameter $\frac{1}{50}$ in. larger than that of the armature core itself. This leaves a clearance of only $\frac{1}{100}$ in. all round, and naturally requires nice work and much care. But it is worth securing, as the output of the machine depends largely on the important question of air gap between armature and poles.

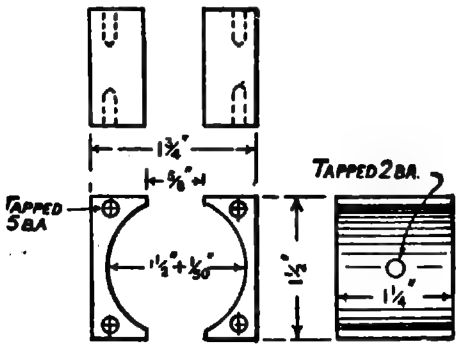


Fig. 31.—Cast-iron Pole-pieces

The magnet complete with pole-pieces attached is shown in Fig. 32. It will be seen from Fig. 31 that the pole-pieces have eight other holes drilled and tapped, one in each corner, for the holding screws of the endplates carrying the bearings; but the drilling of these holes had better be left until the armature is completed, or they may not come properly in line.

The two endplates or bearing brackets consist of aluminium castings, and are exactly alike, except that one of them has the baseplate cast on to it to save work. Details are given in Fig. 33. The central

bosses are bored out to receive Hoffmann ¼-in. ball journal bearings of the light "S" type (Fig. 34), and need to be a good light driving fit on the outer ball races. The recess into which the bearings slide is shown dotted in one view of the endplates (Fig. 33). It is not usual in fixing ball journal bearings of these small sizes to employ any other means of holding them, either in the brackets or on the shafts, except by a

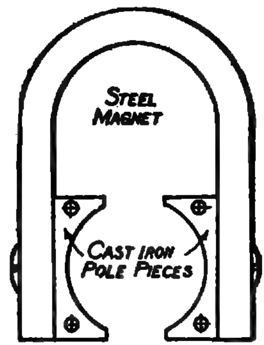


Fig. 32.—Complete Pole-pieces with Magnet attached

"friction fit." Therefore this part of the work demands some care, as the limits between tight and loose fits are very small.

The four holes in each aluminium endplate can be drilled, and the base and ends machined up, square-fitting them to the width of the magnet and its pole-pieces already prepared. Do not, however, drill the pole-pieces until the armature has been completed, as it is necessary to insert this in the tunnel and centre it before marking for the screw-holes.

The body of the armature is a malleable iron

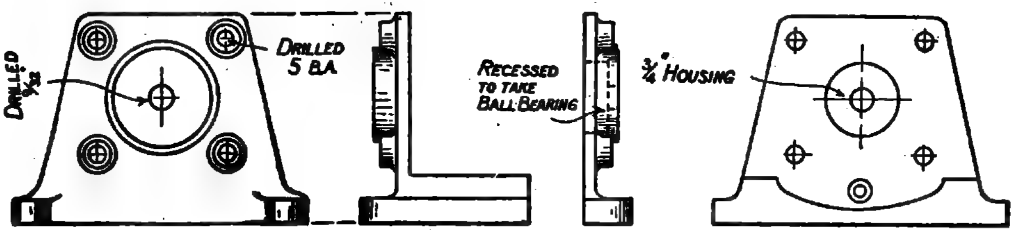


Fig. 33.—Aluminium End Brackets

Fig. 34.—Ball Journal Bearings

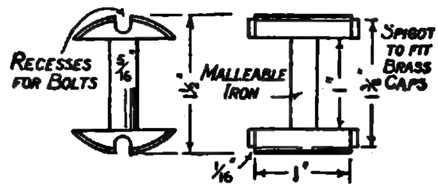


Fig. 35.—Malleable Iron Armature

casting shown in end and side views in Fig. 35, and has two brass caps (Figs. 36 and 37) fitted to it, one at each end, each cap carrying half the armature shaft. The caps themselves are held to the armature casting by means of small bolts or rivets passed through holes in the caps and into the recesses cast into the armature

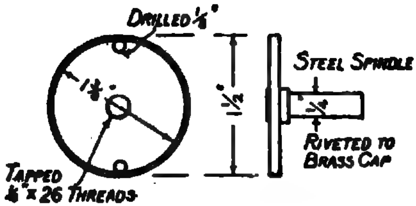


Fig. 36.—Back End Cap for Armature

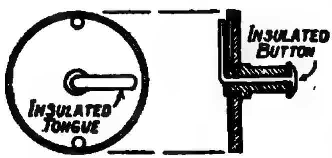


Fig. 37.—Front End Cap for Armature

body. To ensure getting the two shafts into line a "spigot" joint is made at each end between caps and armature body, as shown in Fig. 35. The malleable casting should be first centred and then turned true to size as regards outside diameter between lathe centres, the spigots also being formed at the same time.

The best way to build up the brass end caps to

the armatures (Figs. 36 and 37) is to drill and tap the brasses, screw and rivet them firmly to the steel shafts, leaving them larger than the finished size required, and then mount them by the end of the shaft (left longer for that purpose) in a self-centering chuck, and finish all over to size without removing again. This ensures everything coming up perfectly true and concentric. The extra length can be cut off the steel shafts later, and if they are left a shade large, the journal bearings can also be made a nice fit with fine file and emery-cloth.

One steel shaft end is left solid and takes the driving pulley, while the other is bored and carries the insulated end of the armature winding in a manner to be afterwards described. This construction of armature leaves a clear space for the armature winding, as seen in the view of the assembled armature and end caps (Fig. 38).

The sectional view of the front bearing cap (Fig. 37) indicates the method of making connection between the insulated end of the winding and the metal button against which a spring collecting brush presses. This brush is shown in Fig. 29 at the bottom of the machine, and again in detail in Fig. 39.

To make the connection, drill a central hole through the steel shaft at the front cap end $\frac{5}{32}$ in. in diameter, drive tightly into it a piece of hard fibre or bone, and again drill this with a $\frac{3}{32}$-in. hole, taking every care to get the holes true, or the insulating tube thus formed will have sides of uneven thickness. Push a copper wire through the bone bush, or a large

copper- or brass-headed nail, with another fibre insulating washer of $\frac{1}{32}$-in. thickness at each end and after hammering the end of the nail flat where it comes through inside, turn it up squarely and cut it off flush with the bearing cap. It must project as little as possible inside, or it will get in the way of the winding.

Winding the armature is a very simple matter. Cut some presspahn sheet, $\frac{1}{50}$ in. thick, of the right

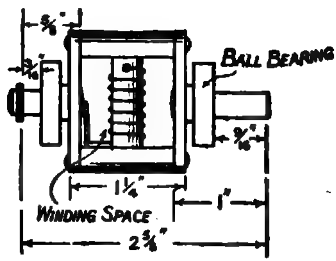


Fig. 38.—Complete Armature, showing Method of Winding and Attaching to Insulated Contact

size to go once round the wire channel of the malleable iron armature body, and two pieces for the flanges or cheeks. These can be fixed with Seccotine or any adhesive compound for the time being.

The starting end of the wire, which is No. 26 double-silk-covered copper, is given a turn round the screw-head shown in the centre of the core (Fig. 38), and the screw tightened down until the head lies flush with the casting. The wire is then wound on with the greatest care not to damage the covering, and with every turn pulled tight and even, until it is seen

that no more can be got on without touching the end caps. The latter are then screwed in position, and the free end of the armature wire soldered to the projecting connection which passes through the front end of the shaft, and the whole soaked in shellac varnish for an hour, and after draining, put in a warm oven for the night. If the varnish is thin, repeat this process next day.

To finish fitting the end flanges carrying the ball bearings, proceed as follows: Cut a piece of brown

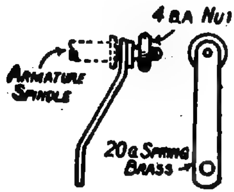


Fig. 39.—Spring Contact Brush

paper of even thickness and free from folds, stout enough so that when wrapped once round the armature it is just possible to push it into the pole-pieces. This locates the armature truly central, and the end flanges with their ball journal bearings in place can then be pushed on the two projecting ends of the shaft, until they bed up against the iron pole-pieces fixed to the permanent magnet. If they do not come up exactly square, the flanges must be faced anew until they do, as the slightest inaccuracy in fitting ball bearings will give rise to trouble.

It will facilitate matters here if, when boring the pole-pieces, the end faces projecting just through the

magnet are also squared off in the lathe. The aluminium flanges also can be faced when the recesses for the journals are formed at one setting in the lathe; it is then impossible for the flanges to come up out of true When this has been arranged to satisfaction, scribe the positions for the four holding screws in the corner of the pole-pieces, these holes having already been drilled in the aluminium flanges. Drill and tap to drawing sizes, and the flanges can be finally screwed on.

The armature should spin quite freely when the permanent magnet has been temporarily removed. When it is replaced, of course, the iron armature cheeks will be strongly attracted by the magnetism of the pole-pieces, and it will run jerkily and tend to stop in two definite positions only, where the armature iron comes next to the poles.

The last thing to do is to fit the spring brush in Fig. 39. This is of hard spring brass or copper held by a single screw to the aluminium flange in front, from which it is insulated by means of fibre or bone washers and a bush. The end of the spring, where the shaft centre bears, is carefully set out and drilled for a 4 B.A. brass screw terminating the other side in a nut for connection to the outer circuit. The head of the screw is slightly hollowed to drop into the centre of the convex button; or, better still, a copper-carbon washer inserted between the two.

A metal or fibre cover is needed to close in the gap existing between the tops of the aluminium end flanges and the armature rotating beneath, and this

may be attached with small screws to the edges of the aluminium.

The driving arrangements will vary so widely, according to the style of machine to which this dynamo is attached, that definite instructions are impossible

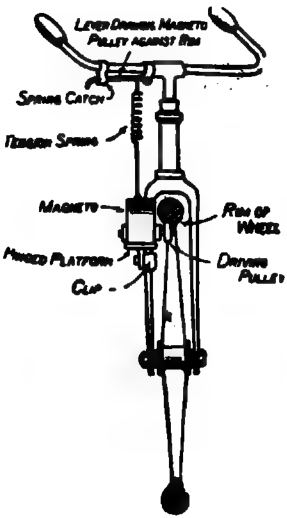


Fig. 40.—Front View of Dynamo attached to Cycle

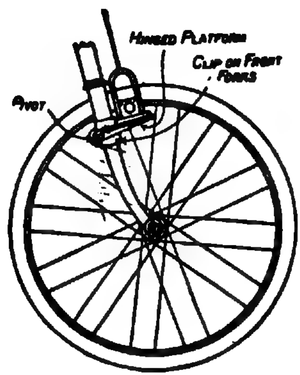


Fig. 41.—Side View of Magneto Mounting

to cover each and every case. As a general rule, friction drives are not altogether satisfactory, because if driven off the rim the latter is seldom true enough to ensure steady running, unless there is excessive pressure between rim and pulley. From the tyre this objection is largely absent, but there is then a question

of carrying all road dust and dirt directly on to the magneto, which is not altogether desirable.

On a pedal cycle one or the other of these alternatives cannot be avoided, and it lies with the rider to decide whether he prefers back- or front-wheel drive. Mounted on a hinged fixing, the friction pulley can be easily arranged to draw on and off the tyre or rim by means of a Bowden wire and lever on the handle-bars.

Another suggestion is given in Figs. 40 and 41. For motor cycles, a separate belt rim and small Whittle belt to the magneto fixed on a separate platform on the crank-case will probably be the best solution.

The little magneto here described will light one 6-volt 6-c.p. headlamp, or one 4-volt headlamp and one 2-volt rear light in series, each taking about 1 ampere.

CHAPTER IV

Hand-driven 20-watt Dynamo

MANY readers who would be glad to make a small dynamo for experimental purposes are debarred from doing so on account of having no means of driving it when finished. It is not everyone who is able to afford an engine, and although foot-power may certainly get over the difficulty if a lathe or an old bicycle adapted for the purpose happens to be available, these too are not always at hand, and one must therefore fall back on hand-driving as the source of power. True, the labour it involves is considerable if kept up for any length of time; but for experimental purposes the need for very long and steady running is quite infrequent.

Such a dynamo as the one to be described will give a far greater output than any primary battery, and, what is of more importance to the amateur, costs nothing for upkeep as a battery does, beyond a little manual labour, and he must regard this philosophically as partaking of the nature of a "home-exerciser." There are no zinc plates or expensive solutions to need frequent renewing as with primary batteries, nor any necessity for frequent and costly recharging as in the case of accumulators. And a final word in favour of the hand-driven dynamo may

be said, in that it does not depreciate if left idle and unattended to, as all batteries do whether primary or secondary.

The type of dynamo described, though not a particularly modern or efficient one, is almost the easiest it is possible for the amateur to fit up, whose workshop facilities and experience are both limited,

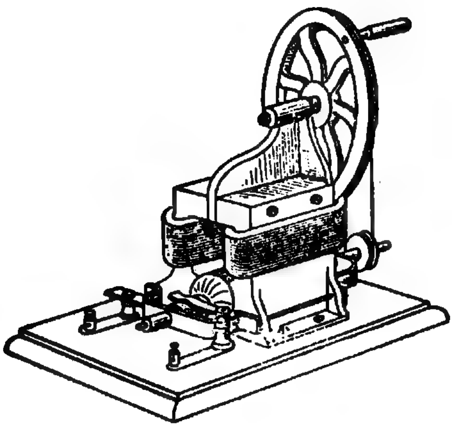
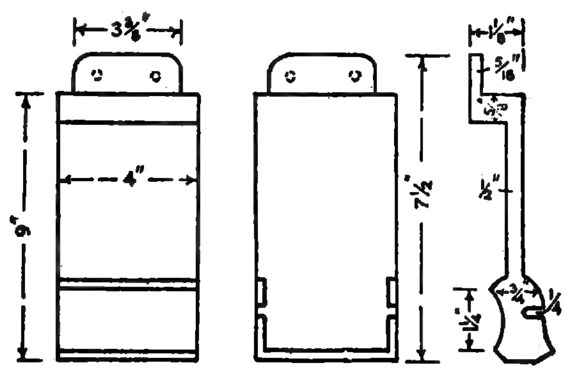


Fig. 42.—Hand-driven 20-watt Dynamo

and if built with even moderate care and run at a reasonable speed, cannot fail to light a 20-watt 16-c.p. metal-filament lamp.

The design, it will be seen from the illustration (Fig. 42), is in general of the "undertype" pattern, consisting of cast-iron field-magnets in two halves, shown in Figs. 43, 44 and 45, with a laminated shuttle armature. Between the two halves of the field casting comes the bracket (Fig. 46) which carries the hand-wheel, a tongue being left on the underside of the

bracket, and all three castings bolted together with two $\frac{5}{16}$-in. bolts passing through the lot. It is not absolutely necessary that these joints should be planed; but the more carefully they are filed or faced up, so that the iron faces come into good close contact, the better for the working of the machine. In any case,



Figs. 43, 44 and 45.—Inside, Outside and Side Views of Field-limb Casting

they must fit together without any "rock," or there will be nothing to limit the diameter of the armature tunnel, which should be $1\frac{9}{16}$ in. finished.

If the castings are clean and good, the armature tunnel need not be bored out, but adjusted as closely as possible to circular form by means of a half-round file. When the work on the field casting has been done, it is bolted down to a polished hardwood base 11 in. by $7\frac{1}{2}$ in. by 1 in thick, centrally placed.

The armature should be prepared next, the steel shaft and dimensions being given in Fig. 49. The core is formed of 1½-in. Siemens H stampings of No. 24-gauge iron, making an overall length of 4 in. when clamped up tight by the locking nut on the shaft. This should be done before the shaft is reduced to its finished size in the bearings, as it will probably throw it a little out of truth otherwise.

The bearing brackets (Figs. 47 and 48) are of two

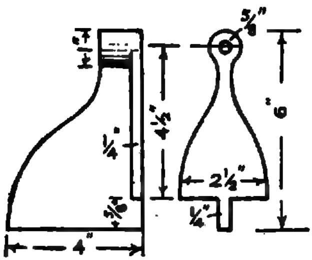


Fig. 46.—Handwheel Bracket

different lengths, Fig. 47 projecting farther than Fig. 48 in order to accommodate the commutator. When machining these brasses, bore and ream the journals first, turning the armature shaft down to just such a size that they will drive on tightly. Then the feet can be squared off by a side tool in the lathe, which will be easier and more accurate than adjusting them by filing. The two brackets are held in position by two long ¼-in. bolts passing from end to end through the slots in the flanges cast on the field-magnets for that purpose. These flanges will be seen in Figs. 44 and 45, and they extend not only along

the sides of the armature tunnel, but across the base of the casting as well, where they form feet and are drilled for bolting to the baseboard.

A strip of stout brown paper is rolled round the armature core, and then pushed tightly in its tunnel. This centres the armature while the bearing feet are tested to see whether they bed flat on their seatings, and if not they must be corrected with a file until they can be screwed up hard without pinching the armature shaft.

Remove the armature and bearings, and then

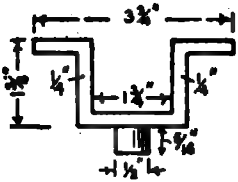


Fig. 47.—Front Bearing Bracket

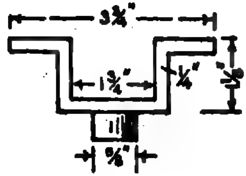


Fig. 48.—Back Bearing Bracket

proceed with the commutator (Fig. 50). This is simply a piece of hard fibre a driving fit on the shaft, having a length of brass tube fixed to it by means of short brass screws, which must on no account touch each other or the shaft in the centre. Fix the brass tube with four screws, two in each segment, and make a fine saw-cut lengthwise as shown just through the brass down to the fibre on opposite sides of the centre, so that the tube is divided into two exact halves, each one well insulated from the other. When driving the commutator on the shaft see that the slits

come in the centre of the wire channels of the stampings.

The pulley is a simple matter, and can be turned either from metal or hard fibre to the dimensions given in Fig. 51. A flat filed on the shaft and a small metal wedge driven in serve to fix it securely.

Assemble the fields, bearings and armature in

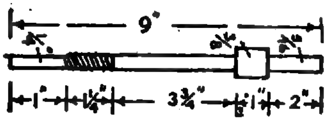


Fig. 49 —Armature Shaft

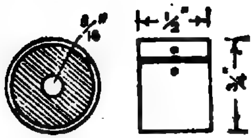


Fig. 50.—Commutator

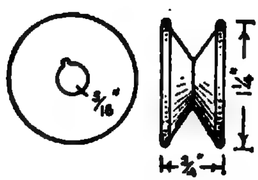


Fig. 51.—Pulley

position on the base, and then construct the two brush pillars (Fig. 52). These are of two different heights, since one carries a brush underneath the commutator, and the other over the top. They are turned from solid brass rod, the shape being immaterial, and have milled-head nuts at the top by which to clamp the brushes.

The brushes (Fig. 53) are of copper gauze folded into three or four thicknesses, and provided with a

piece of springy brass shaped as shown in the under part of this figure, by which sufficient pressure can be maintained by the brushes on the commutator. The screws which pass up through the wood base to hold the two brush pillars (Fig. 52) require spacing so that they come in line with the centre of the commutator 4 in. apart. To collect the current, strips of brass sheet about No. 22 gauge are made according to

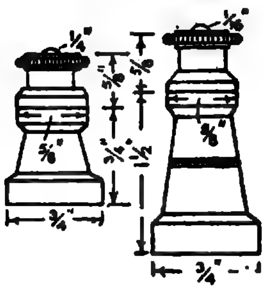


Fig. 52.—Brush Pillars

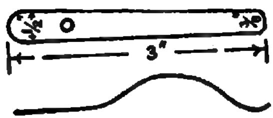


Fig. 53.—Brush Plates

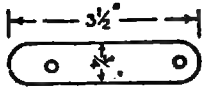


Fig. 54.—Connecting Strips

Fig. 54, and screwed one under each of the brush pillars on top of the baseboard. The other extremity of these strips then receives an ordinary brass terminal with a wood screw down into the base.

The driving arrangements consist of a large hand-wheel (Fig. 55) having a V-groove mounted on the bracket (Fig. 46) already provided for it, and this will need a steel spindle (Fig. 56) on which to revolve. This spindle is bolted fast to the bracket, leaving the wheel to run free, with its groove just over the centre of the pulley on the armature shaft below.

The handle (Fig. 57) is of hardwood, nicely polished, and revolves on a steel pin (Fig. 58) in which a groove has been turned towards one end for a set-screw (shown in the handle) to engage in to prevent it working off.

For driving, nothing is better than the close-coiled steel-spring wire known as "fan-belting." If this is used it should be as small as possible, not larger than

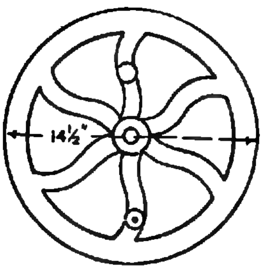


Fig. 55.—Hand-driving Wheel

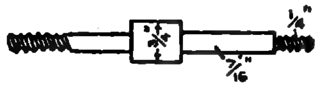


Fig. 56.—Steel Spindle for Driving Wheel

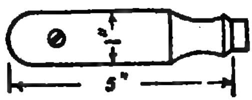


Fig. 57.—Handle

¼-in. diameter. Failing that, use ordinary 3/16-in. round leather belting, with a steel hook-and-eye fastener, well stretched before it is put on. The advantage of the steel fan-belting is that it never stretches. Leather belts, on the other hand, should be run off the grooves all the time they are not in use.

Both the armature and fields of this dynamo need winding with No. 22 d.c.c. copper wire. The armature requires about 5 oz. and the two fields 2 lb. between them. Before winding, smooth off the ironwork wherever the wires are to be laid, and paste over it

a layer of thick brown paper. When dry varnish with shellac, and proceed to put on the wire regularly and evenly, every turn in its proper place, and pulled as

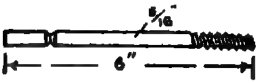


Fig. 58.—Pin for Handle

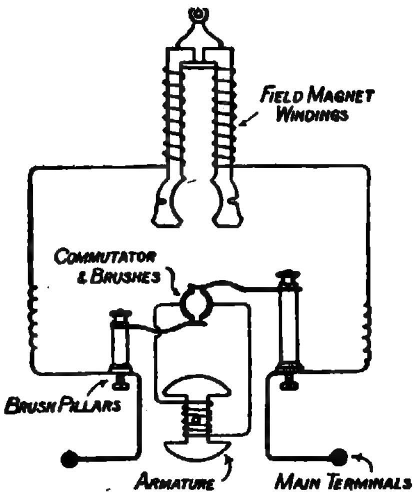


Fig. 59.—Diagram of Connections

tightly as it will bear without stretching until the proper amount is got on.

In the case of the field windings, the finishing ends can be secured by winding in with the last few turns of the finishing layer a piece of stout twine, and using

this with which to tie the end. Both fields are wound in the same direction, and connected together so as to give proper N and S polarity. This can be easily tested by passing a small current through the windings, and testing the resulting poles with a compass needle.

There must be no leakage of current from the windings to the ironwork anywhere, either with fields or armature. Varnish the coils as soon as finished with shellac or other insulating compound to protect them from damp. The two ends of the armature windings require to be connected to the two half sections of the commutator by means of a spot of solder at the back edge of the segments out of the way of the gauze brushes.

A diagram showing the connection of the whole machine is given in Fig. 59, and if all instructions are observed, with moderate care the result should be a really serviceable machine, and a great source of satisfaction to the possessor.

CHAPTER V

Two Miniature Dynamos

IT is not possible to build an extremely small model dynamo that will generate any current, although electric motors have been built so small as to weigh only a few grains, and to run well when supplied with a very weak current. About the smallest working dynamo that can be built is one having an armature 1 in. in diameter by 1 in. long.

Miniature Undertype Dynamo.—The accompanying illustrations show a small undertype dynamo of about 6 watts capacity. When run at a speed of 3,000 to 4,000 revolutions per minute, the machine should generate 2 volts 3 amperes, or if connected to two bichromate pint-sized cells in series or to a 2-volt accumulator, will run at a great speed as a motor.

Apart from making the patterns, little or no lathe work is required, and the only tools necessary are drills and taps and a file or two, a fact that will no doubt appeal to those having limited workshop facilities.

Fig. 60 shows the finished machine, which is built up from a single soft-iron casting, with two brass bracket bearings. The armature can also be a solid casting in such a very small machine, as this saves

labour in fitting up, and efficiency is not so much a consideration. The castings are procurable if the worker does not care to undertake the pattern-making.

In fitting up the castings the work will be best carried out in the following order. Full detailed working drawings and winding diagrams are shown by Figs. 61 to 64, similarly lettered so that no mistake can occur even at the hands of the beginner un-

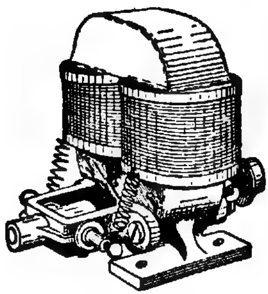


Fig. 60.—Miniature Undertype Dynamo

acquainted with dynamos. First clean up the armature and field-magnet castings A and B with a file, taking off all roughness and sharp corners where the windings will come. Then centre the armature core carefully at each end, also the pulley casting C, the brass castings forming the bearings D, and the fibre commutator bush G, drilling each one through with a $\frac{3}{16}$-in. drill.

The armature, pulley, and commutator bush each require to be a light driving fit on the steel shaft E, and the bearings must be a free or running fit. See

that the armature and pulley both run quite true on the shaft, correcting them, if necessary, with a file. Then secure in their proper positions by drilling a small hole radially through the shaft and driving in a small steel pin.

With very small machines trouble is frequently experienced in the construction of the commutator, owing to the small space available in the centre bush for screws to hold the segments. A method of overcoming this difficulty is shown in the description of the commutator for this machine.

The commutator G when finished is divided into two equal parts by a narrow saw-cut shown. Before doing this, two other narrow parallel saw-cuts (seen in Fig. 65) are made on each side of the shaft, as close to it as possible without touching, into which strips of sheet brass are fitted and soldered, and afterwards filed off flush. This keeps the separate segments of the commutator together when the tube is sawn through on each side. Both halves of this commutator must be insulated from each other, as well as from the shaft.

The armature core, mounted on its shaft, is next tried into the bore between the pole-pieces (or "tunnel"), the latter being eased out with a half-round file, if necessary, until it will just push tightly into this tunnel with a single thickness of stout brown paper wrapped round it. Leaving the armature in this position, remove the pulley and slip on the two bearings, one at each end.

These will require a little filing at their feet until

they fit nicely on the field-magnet carcass. Mark off the position for the holding-down screws H (Fig. 61), drill the bearings with clearing holes and the carcass tapping size for four 5 B.A. screws. Finally take out

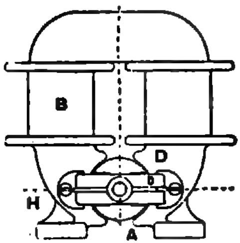


Fig. 61.—End Elevation

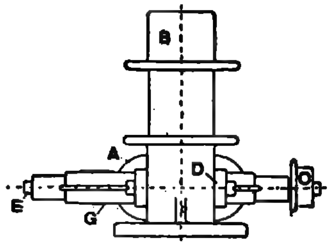


Fig. 62.—Side Elevation

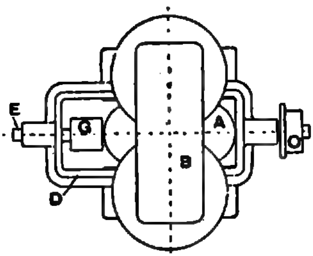


Fig. 63.—Plan

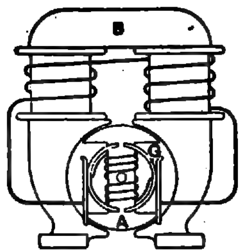


Fig. 64.—Winding Diagram

the armature, remove the brown paper, and replace the bearings, further adjusting their feet, if necessary, with a fine file carefully used, until they can be screwed down hard without binding the shaft. Small oil holes drilled at the top into the bore for the shaft will complete these. End play is limited by a fibre collar

driven on to the shaft inside the bearing at the pulley end.

The brush gear will finish the mechanical part of the work. This is shown in Fig. 65. The side members of the front bearing bracket have bosses cast on which are to be drilled through centrally, to admit of brush holders of the spring-plunger type. The brush holders must be insulated from the bracket by thin fibre or presspahn washers, the insulation being

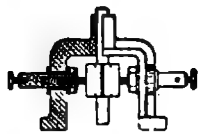


Fig. 65.—Details of Brush Gear and Commutator

shown in the sectional part of Fig. 65 by heavy black lines.

The brushes themselves consist of copper gauze rolled up tightly into cylindrical form, and made an easy sliding fit in the holders, which also serve as terminals. The brushes are fed up to the commutator by light springs as shown, and the commutator slits are placed in line with the iron cheeks of the armature core as shown in Fig. 64.

The dynamo is now ready for winding, and reference to Fig. 64 will make it clear as to the manner of connecting up. All parts where the wire comes, namely, the pole-pieces or magnet cores, and the slots in the armature, must be carefully covered with presspahn or insulating paper cut neatly to

shape and fixed temporarily with a touch of sealing-wax.

No wire must be allowed to come into contact with bare metal, except, of course, where the ends of the armature wires are soldered to the commutator, and the field-magnet connections affixed to the brushes.

The method of connecting employed here is known as "shunt winding." Two paths are open to the current generated by the armature, one by way of the terminals to the main outer circuit, while the other is "shunted" round the field coils to energise the field-magnets; as this circuit is always closed the dynamo is self-exciting.

The armature and field windings are laid on direct by hand into their final position, each with as much No. 22 gauge d.c.c. copper wire as they will hold After first insulating with thin presspahn, both armature and field coils should receive as many turns of wire as it is possible to get into the space provided, in order to ensure the machine working satisfactorily.

Should there be any trouble in getting the machine to start up, pass current through the fields from a 4-volt battery for a few moments, first taking out the armature or removing the brushes, so as to well magnetise the field. For a finish, the metalwork may be enamelled and the windings coated with shellac varnish.

Miniature Manchester Type Dynamo.—A popular type of model, such as the "Manchester," can be built according to the accompanying scale drawings, and if well made will light fully a 4-volt 4-c.p. Osram

lamp. Fig. 66 shows the machine in side elevation, Fig. 67 in end elevation, and Fig. 68 in plan. Fig. 69 is a winding diagram showing how to wind and connect up the armature and fields to the brushes, while Fig. 70 shows the commutator and brush gear.

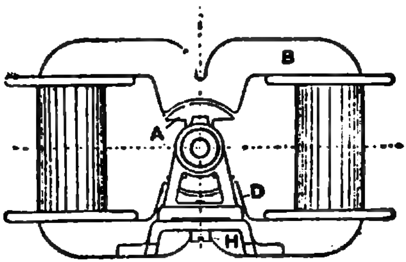


Fig. 66

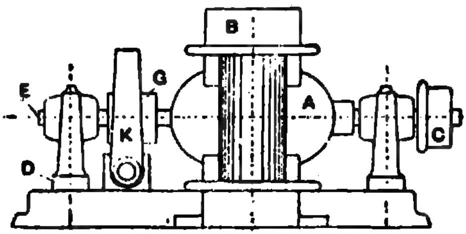


Fig. 67

Figs. 66 and 67.—Side and End Elevations of "Manchester" Dynamo

The method of building the commutator is the same as for the commutator of the undertype dynamo just described. A hard fibre rod has a piece of brass tube driven tightly over it, and two parallel saw-cuts are then made at each end, just missing the centre hole

where the shaft passes through. These cuts only extend $\frac{1}{8}$ in. in from the ends of the commutator, as will be seen in Fig. 68, and receive strips of brass

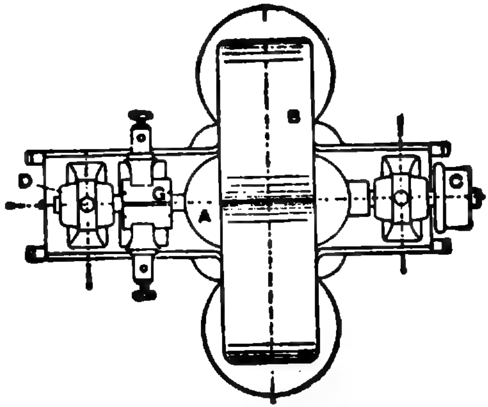


Fig. 68.—Plan of "Manchester" Dynamo

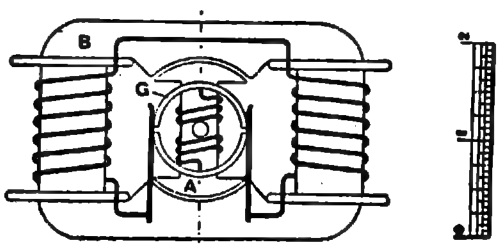


Fig. 69. - Winding Diagram and Scale

sheet soldered in. This keys the two halves of the commutator together when divided subsequently.

The letter references in the figures are: A the armature (a solid H-casting in this case), B the field-

magnet casting, C the pulley, D the bearings (brass), E a silver steel shaft, G the commutator, K brush gear, which also indicates how the spring brass brushes pressing on the commutator are fixed to a fibre base and secured by terminals. H are screws holding the bearings D down to the base of the machine.

The windings will consist of 1 oz. of No. 24 d.s.c. wire for the armature, and 5 oz. of No. 22 c.c. wire on the fields.

The instructions regarding the general construction of the undertype dynamo apply equally well for this

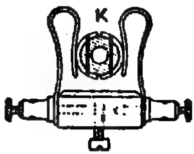


Fig. 70.—Brush Gear and Commutator

one, therefore no purpose would be served in repeating them. As regards design there is little to choose between the two types, but probably the undertype will be the easier to construct.

Either of them, for use as a motor, may be made considerably smaller and still work quite well, but an attempt to reduce the size with a view to running as a dynamo would most probably result in failure.

If constructed according to the scale drawings, at a speed of 3,000 revolutions per minute such a machine as the last one described will excite its own fields, and provide sufficient current to light fully a 4-volt or 6-volt lamp. Also it will run as a motor from a 4-volt accumulator or primary battery.

CHAPTER VI

Methods of Driving Dynamos

DRIVING a dynamo, even of small power output, necessitates the expenditure of considerably more energy than might be expected, especially as any small dynamo can easily be rotated by hand.

Two factors must always be taken into consideration when arranging for the necessary motive power; these are—firstly—that the electrical energy given out by the dynamo is much smaller than the mechanical energy expended in driving the dynamo.

For example, a dynamo with a 75-watt output is theoretically giving out $\frac{1}{10}$ horse-power of electrical energy, since there are 750 watts per one horse-power. The mechanical power necessary to drive such a dynamo is determined by the electrical efficiency of the machine, by the mechanical excellence of the bearings, friction in the brush gear, and by the efficiency of the transmission. Roughly speaking, the power input should be about double the output of the dynamo; thus a 75-watt dynamo would need about $\frac{1}{5}$ horse-power to drive it efficiently.

The second factor to consider carefully is that, to generate a respectable current at a useful voltage, the dynamo must be rotated at high speed, varying from about 4,000 to 5,000 revs. per minute for very small

machines down to about 2,000 to 2,500 revs. per minute for machines of about 75 watts output.

Methods of driving small dynamos are numerous; for example, the hand-power machine described in Chapter IV, which is admirably suited for occasional use and for experimental purposes. In the model sphere, or for quite small machines of low output, a small steam engine and boiler, as in Fig. 71, is very effective and is capable of continuous running for several hours' duration if the boiler is suitably fired—for example, by a gas burner—and if an adequate feed water supply is maintained.

For more serious work a small gas engine, or a self-contained petrol electric set is exceedingly convenient and eminently practical. It will be appreciated, of course, that steam, gas and petrol engines are highly practical for larger dynamos, but in this handbook only small-power machines are dealt with, hence the remarks on motive power should be read in that light.

Wind power is quite practical for dynamo driving; the necessary windmill is preferably of the American or multi-armed variety. An average size of wheel for the machines described in this book is between 2 and 3 feet diameter. The most efficient method is to put the dynamo at the top of the windmill and drive it directly, as this avoids transmission losses; well-insulated cables—preferably with a lead coating properly earthed—are essential to avoid current and voltage losses in the feeder lines.

A simple 2 ft. diameter two-bladed air screw—of the aeroplane type—mounted directly on the dynamo shaft is often effective when fairly high winds are prevalent.

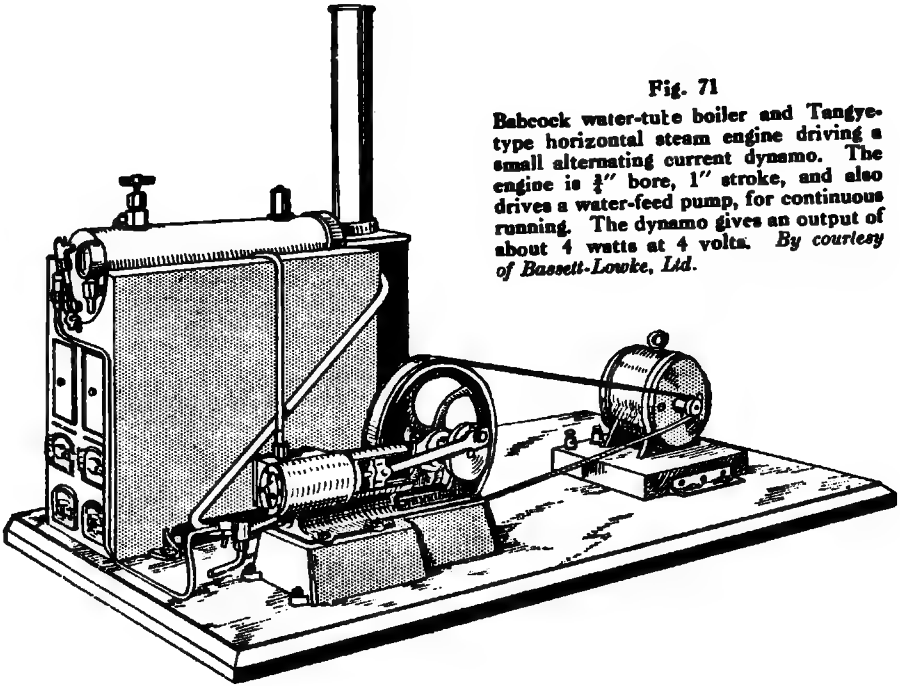


Fig. 71

Babcock water-tube boiler and Tangye-type horizontal steam engine driving a small alternating current dynamo. The engine is ¾″ bore, 1″ stroke, and also drives a water-feed pump, for continuous running. The dynamo gives an output of about 4 watts at 4 volts. *By courtesy of Bassett-Lowke, Ltd.*

Water wheels when in existence are probably the most economical motive power, but being slow speed, need a suitable train of gears or a multiple chain drive to impart the necessary velocity to the dynamo shaft.

A heavy weight—of the order of ½ cwt. or so—in conjunction with a block and tackle system, arranged so that the weight falls slowly and rotates rapidly a drum or spindle, provides—when conditions are practicable—an inexpensive driving power that will give an hour or so continuous run. The labour involved in raising the weight again is the chief deterrent to the widespread use of this simple expedient.

Sand wheels are a feasible form of motive power and are simply a water wheel of the overshot type on to which a continuous stream of dry sand is allowed to fall. After passing the wheel the sand falls into a hopper or box, which when full can be removed and the contents replaced in the upper sand bin. By arranging two receptacles to slide in and out like drawers the machine can be kept running for lengthy periods without serious demands on the attendant. The upper receptacle is allowed to fill and is then drawn out and the contents replaced in the upper sand bin; meanwhile the second or lower receptacle is allowed to fill. The upper one is then replaced and the lower withdrawn, and emptied and replaced; in this way there is little or no loss of sand and the attention required is reduced to a minimum.

Obviously, in small workshops and other places where a power drive is installed, it is a simple matter to fit a suitable-size pulley on the main shaft and drive the dynamo directly.

The two most successful and widely adopted means of transmitting the power from the driving source to the dynamo is by means of an endless rubberized belt, or by direct coupling, but in every case the utmost care must be taken to ensure perfect alignment of the shafts

A Pelton wheel or high pressure water motor is very practical for dynamo driving, but it consumes an enormous amount of water and in many districts such a water consumption is not permitted except with the written sanction of the water supply authorities—accompanied usually by an increase in the amount of the water-rate chargeable.

A practicable direct-coupled Pelton wheel and dynamo is shown in Figs. 72 to 77, and will give an output of about 8 volts 2 amperes with 50 lb. water pressure, or about half the output with a pressure of about 35 lb.

The best position for the machine should be determined by hydraulic considerations; and the water must be taken from the rising main, and when it is desired to conserve as much of the used water as possible, the machine should be put in the roof and discharge into a large cistern, with an overflow pipe at least one-and-half times the bore of the exhaust pipe on the machine.

The water from this cistern can be used for many domestic purposes, for the garden and so forth, but should not be used for drinking or culinary purposes.

To make a dynamo and water motor, a set of the necessary castings in iron will comprise the dynamo field-magnet, bearing, baseplate, and water-motor casing; the brass castings will consist of the

brush rocker, brush holders, wheel hub and cups, and nozzle. Figs. 73 and 74 are reproduced two-fifths full size, so that the dimensions of every part can be ascertained without trouble.

The method of fixing the armature stampings on the shaft is unusual, but it has proved quite effective,

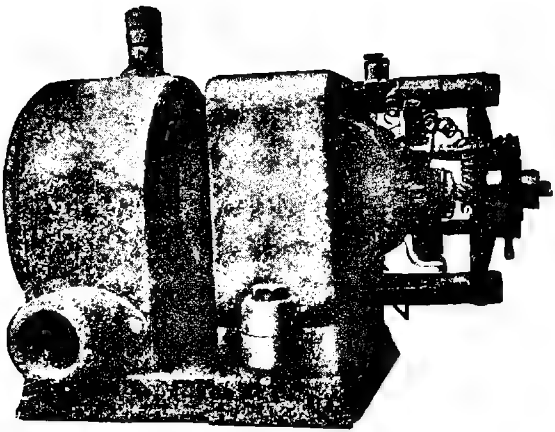


Fig. 72.—Direct-coupled Water Motor and Dynamo

the stampings being held in place by two brass collars, secured to the shaft with grub screws.

The shaft is ¼-in. diameter silver steel, and one of the collars is first secured on it in its proper position. Against it should rest a disc of iron $\frac{13}{16}$ in. in diameter and of about No. 16 s.w.g., followed by the correct number of stampings, which have eight slots and are 1⅝ in. in diameter. A similar iron washer is then placed against the last stamping, followed by the other brass collar. A strip of oak, which just fits tightly in

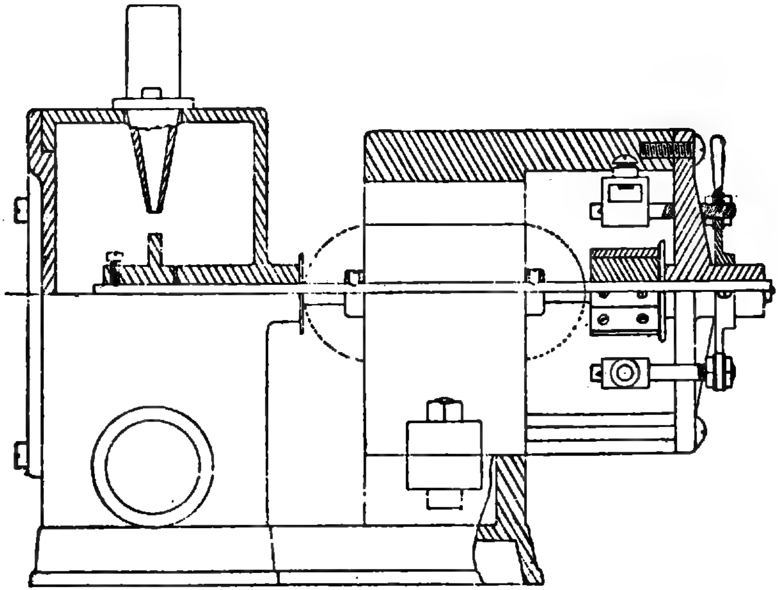


Fig. 73.—Part Sectional Side Elevation of Dynamo and Water Motor

one of the armature slots, is then placed in position to keep all in line, and then the two collars are gripped between the jaws of a parallel vice and forced tightly together. Whilst in the vice a small countersink is

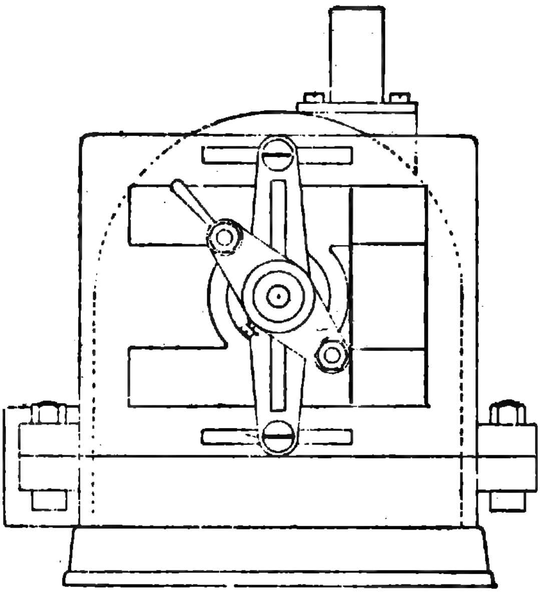


Fig. 74.—End Elevation of Dynamo

made on the shaft through the hole in the loose collar this being for the reception of the grub screw.

The armature is prepared in the usual way and is wound with No. 22 S.W.G. wire, two coils per slot as shown in Fig. 77

The construction of the dynamo follows generally on the lines described in other Chapters.

The water-motor casing should be drilled with a couple of $\frac{1}{4}$-in. clear holes in the base for holding-down bolts, and then lined up with the dynamo shaft, and the corresponding holes in the baseplate marked off and drilled. It must be noted now if any packing is required for the casing, in order to bring it into alignment with the shaft, as no binding must

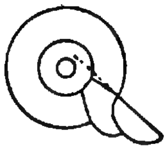


Fig. 75.—Side Elevation of Wheel with One Cup in Position

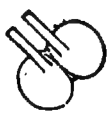


Fig. 76.—Plan of Bucket

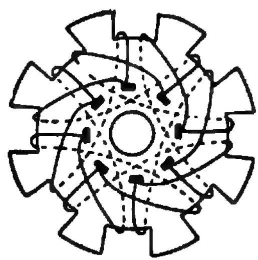


Fig. 77.—Armature Winding Diagram

take place when all is bolted up. This can be done with strips of tin placed under the corners.

The brush rockers are filed up to the proper size. Copper gauze brushes are used to collect the current, being pressed forward by a couple of light spiral springs coiled on the brush-holder rods. These rods are screwed at one end for a short distance, and fitted with a couple of nuts, thin fibre washers being interposed between them and the rocker. The holes in

the latter are bushed with thin strips of sheet fibre bent into a circle and forced in. In Fig. 73 the rocker and holders are not drawn exactly in their correct position; but are shown thus for clearness. The correct position will be obtained by trial.

The bobbins for the field-magnets are made from sheet tin soldered together, and when insulated with brown paper, should be wound full with No. 23 S.W.G. copper wire. The terminals of the dynamo should be attached to the webs at each side of the top support of the end bearing, by means of insulated holes.

For the Pelton wheel, the sides and edge of the hub should be filed up bright, also the inside of the webs of the cups, and these latter made a tight fit on the hub sides as shown in Fig. 75, where only one cup is shown. Fig. 76 is a plan of a cup. Notice the angle at which the cups are placed on the hub, and this must be the same as the one shown.

Having fitted all in place the cups must be sweated in position with soft solder. The cover of the casing is secured with three screws, a thin leather joint washer being interposed to make same watertight, and grummets of soft twine placed under the heads of the holding-down bolts. The jet should be bored out at the nozzle about $\frac{1}{8}$ in. in diameter, the correct size can only be determined by experiment when the machine is completed. The nozzle hole should taper in the manner shown in Fig. 73. Two screws secure the jet in place; but the position of these can best be determined by trial with the dynamo running.

CHAPTER VII

Three Small Electric Motors

The uses and applications of the electric motor are innumerable, lending itself as it does to the transmission of power in confined and awkward situations with a degree of flexibility possessed by no other form of motive power.

It is not an uncommon thing to find an electric motor actually incorporated with the framework of modern machine tools, and forming part and parcel of the whole as a complete unit in itself, capable of being disposed in any convenient site without regard to belts, line shafting, pipes, or other power-transmission gear.

An electric motor, being fed by a flexible electric-cable, can be stowed away in almost any situation, an advantage which counts for a great deal when laying out a modern workshop; it is always ready for its work at a moment's notice, and consumes only so much current as is called for by the nature of the work being done—factors which go far to establish its claim as a successful rival to steam, gas, or oil.

Perhaps one of the most significant features of the electric motor, more especially with regard to the smaller sizes, is the facility with which it can be built

in a variety of designs, each type being fitted for a particular purpose, and so accommodating itself to the space at disposal as to render it practically the only kind of driving mechanism possible with such appliances. It is thus admirably adapted to the requirements of the model-maker. It is almost imperative that a model should work when built, or it will lose half its attractiveness; and the difficulty of finding a neat and effective form of driving mechanism appears to be met by the use of the electric motor.

The design of motor illustrated in side and end elevations and plan by Figs. 78, 79 and 80 respectively is specially suitable for the propulsion of model tram-cars, motor-cars, launches, and the like, being built very low. This type of motor embodies the maximum power and efficiency attainable, taking the size and weight into consideration.

The main features are: (1) slotted drum armatures; (2) disc commutators, greatly economising space; (3) fixed position of brushes at all loads; and (4) series winding, which gives great initial torque, or starting power; and as the whole of the work can be manipulated on a 3½-in. centre lathe, there should be no difficulty, with the aid of the working drawings and instructions here given, in building a motor of this description.

As very few readers will have facilities for foundry work, it is assumed that the castings will be purchased ready made in the usual way; hence detailed instructions for making the patterns are unnecessary. The

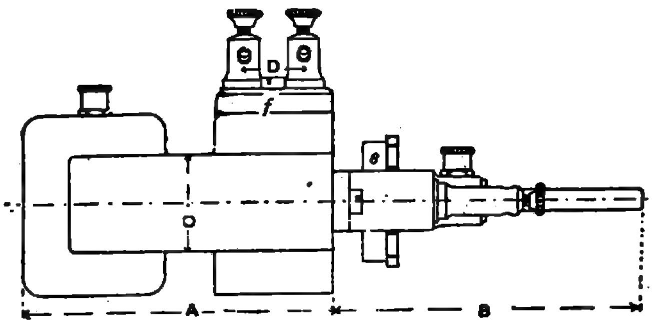


Fig 78

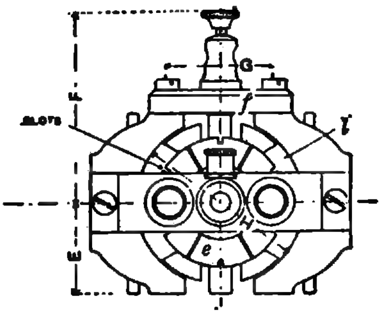


Fig. 79

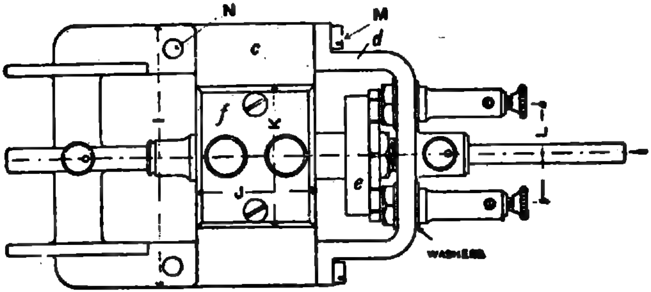


Fig 80

Figs. 78, 79 and 80.—Side and End Elevations and Plan of Small Electric Motor

pattern-making, however, presents no great difficulty. It will suffice simply to make a solid model in wood from the dimensions given in Table A, allowing $\frac{1}{8}$-in. per foot for shrinkage of the castings when cooling, and the usual slight draft or taper on the patterns to enable them to leave the moulding sand easily. They may also with advantage be divided along the horizontal centre line (Figs. 78 and 79) for convenience in moulding. The tunnel or space *b* (Fig. 79), where the armature rotates, should be left solid, with a circular core projecting three times as far as the length proper of the tunnel, and $\frac{1}{8}$ in. less in diameter, to allow of machining out true to the finished size in the lathe.

Having procured the castings, one off the carcass *c* (Fig. 80) in soft grey iron, and one off the bearing bracket *d* in brass or gunmetal, both clean and well annealed, the first step will be to machine out the armature bore. This is best accomplished by bolting the carcass firmly on the lathe faceplate, after carefully squaring the flanges at the back, so that it beds firmly without rocking. Care must be taken to get the thick centre flange at the back exactly centred sidewise, as this is bored at the same setting to receive the end of the armature shaft. With a good stiff boring tool in the slide-rest, and the back gear on, the tunnel is now bored out exactly to the dimensions given in Table A.

The first cut should be deep enough to go well under the rough surface and hard skin of the casting into the soft metal, or the process will be difficult. A

cut should also be taken off the face of the carcass to square the ends of the poles.

Before disturbing the fixing on of the faceplate, make a depression in the thick web at the back with a square centre in the back poppet passed through the inside of the tunnel; and with a twist drill held in a hand vice, or dog, guided and led forward by the back centre of the lathe, drill in to the required depth for the back journal of the armature shaft. It is of great

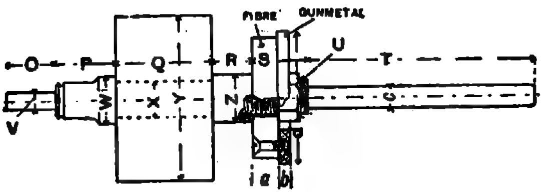


Fig. 81.- Details of Armature and Commutator

importance that this hole is made truly concentric with the armature bore.

This completes the machining required on the carcass, and it may now be taken off the lathe and the armature (Fig. 81) taken in hand. Cut a mild steel bar of the required size to the proper length (see Table A), and square up the ends with a file, until it will stand upright when placed on end on a level surface. Take a pair of dividers set a trifle less than half the diameter of the shaft, and, holding one leg against the side, scribe several lines across the shaft end from different positions; the small space or enclosure left by these lines will mark the position

for the centre, which may now be lightly dotted in with a centrepunch.

Now try the shaft between the lathe centres, revolving it with the fingers while a tool set in the

TABLE A.—DIMENSIONS

PART.	No. 1 SIZE.	No. 2 SIZE.	No. 3 SIZE	PART.	No. 1 SIZE.	No. 2 SIZE.	No. 3 SIZE.
A	2¼"	3¼"	4½"	S	½"	9/16"	11/16"
B	2½"	3½"	4½"	T	1⅝"	2⅜"	2⅜"
C	⅝"	1"	1¼"	U	¼"	⅜"	⅝"
D	½"	⅝"	1"	V	5/16"	9/16"	¼"
E	11/16"	1"	1¼"	W	⅜"	½"	¼"
F	1½"	2"	2¼"	X	¼"	⅜"	⅜"
G	⅝"	1⅛"	1⅝"	Y	1¼"	1¼"	2½"
H	Y + 1/16"	Y + 1/16"	Y + 3/16"	Z	⅝"	⅜"	¼"
I	1¼"	2¾"	4¼"	a	7/32"	¼"	¼"
J	[illegible]	1¼"	1⅞"	b	3/32"	⅝"	5/32"
K	1"	1⅜"	2"	c	13/16"	7/32"	⅝"
L	¾"	1 1/16"	1⅜"	d	1"	1⅝"	2"
M	4 B.A.	4 B.A.	0 B.A.	e	5/16"	⅝"	½"
N	¼"	3/16"	¼"	f	⅝"	⅝"	1½"
O	⅜"	¼"	⅜"	g	7/32"	3/16"	9/32"
P	⅜"	⅝"	⅜"	h	2 B.A.	9/32"	7/16"
Q	⅜"	1"	1⅜"	i	7/32"	5/16"	13/32"
R	⅝"	7/16"	¾"	j	8 B.A.	5 B.A.	2 B.A.

slide-rest is fed up to it until it just touches: it will then mark the highest side, if there be any. Test the shaft thus at both ends, and then, if necessary, correct the centres by carefully drawing the centre-punch mark towards the high side until the shaft runs as nearly true as possible in the centres.

It is now ready for drilling, and the best tool to use for this is the Slocomb centering drill, which drills and countersinks at one operation. If this is not available, see that the small hole is deep enough to

clear the point of the lathe centre, or the shaft may subsequently run out of truth; and as a further precaution, before roughing it down to size, square the two ends in the lathe exactly with a side tool, and file off any burr left round the centre hole.

The shaft is next turned to size roughly, all dimensions being left $\frac{1}{32}$ in. full, except the threaded portion, which is turned to the finished size and

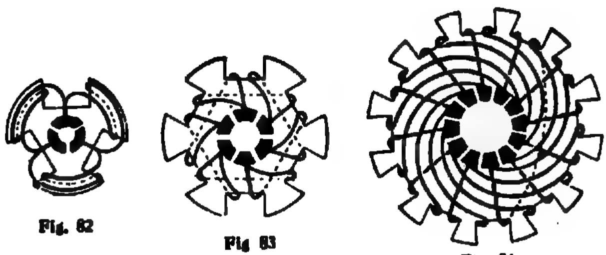


Fig. 82

Fig. 83

Fig. 84

Figs. 82, 83 and 84.—Armature Winding Diagrams

screwed. The reason for this is that threading the shaft with dies almost always puts it slightly out of truth, and it is better to have sufficient margin of metal for correcting this.

After fitting a nut to the threaded portion, and squaring up the ends, turn down to size the length which is to be occupied by the stampings, leaving them a square shoulder to butt against. They should be an easy driving fit on the shaft; and for these small sizes no insulation is required, either between

the stampings and shaft or between adjacent core discs.

The next operation is to assemble the stampings, which will resemble either Figs. 82, 83, or 84, according to the size of the motor, getting all the slots in line, and clamping up tight by means of the end nut.

If the previous work has been properly carried out, the stampings should run quite true on the shaft when rotated between the centres. The most frequent cause of the shaft springing lies in the fact that the clamping nut has not been truly squared on the shaft, or that the thread is "drunk." If all is satisfactory, however, proceed to finish up the shaft to the dimensions given, and polish with a fine file and emery in the usual manner.

The commutator *e* (Figs. 78, 79 and 80) is of the disc type, and consists of a gunmetal ring screwed against a fibre back, the slots being afterwards cut and filled in with mica. The centre hole is of sufficient size to slip easily over the shaft and back against the face of the nut holding the stampings, being finally secured with a small clamping nut in front. It is a simple and easily constructed form, and requires no particular treatment in the making, except as regards screwing on the gunmetal ring to the fibre. The fibre back should be first prepared, and the position of the holes set out and marked on the back—if possible, by aid of a division plate in the lathe. One hole only is then drilled right through the fibre and brass (noting that the screw is tapped into the brass only), and one screw inserted and driven tight home.

With the ring thus fixed firmly in position, proceed to drill all the other holes, tapping size, right through the fibre and brass, the holes in the fibre being opened out afterwards; and before taking apart, mark the fibre and ring so that they may be put together again in the same position. This is the only means of ensuring that the holes are in proper alignment.

When all the holes have been drilled and tapped, remove the burrs and screw up finally as firmly as possible. Mark out the position for the slots midway

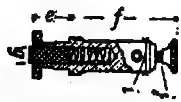


Fig. 85.—Brush-holder

between the holding-down screws, and carefully divide the segments with a hack-saw, the cuts being about $\frac{1}{32}$ in. wide. Slips of mica are then driven in hard, with a little shellac varnish to assist them to hold, and when dry the commutator is faced off in position on the armature. Small slots are filed on the edges of the brass ring to receive the armature connections, which will presently be soldered in.

The front bearing bracket *d* (Fig. 80) and brush-holders *g* (Fig. 85) next require fitting. The round boss on the end of the brass bracket is gripped in a self-centering chuck, and the centre hole drilled true to the size of shaft it is to receive; before removing, a light cut is taken off the projecting feet. The latter requires a sharp fine-pointed tool, and care in using

it, or the work will be thrown out of truth and will not bed square on the pole-faces. The outside of the boss is afterwards turned up and polished on a mandrel.

The brush-holders are hollow, and contain a brush made of copper gauze tightly rolled up, sliding loosely in the bore and fed forward by a spiral spring. Neither these nor the terminal boards *f* (Figs. 78, 79 and 80) present any special difficulty; it is simply necessary to adhere to the dimensions given in the table.

In drilling and screwing the front bearing to the carcass, the correct way to ensure the armature running concentric with the bore is to wrap a strip of brown paper evenly round the armature core until it will just push tight into the bore. The front bracket, after drilling the feet, is then slipped on over the journal and held firmly while the outlines of the holes are scribed on the pole-faces, and after removing the bracket and armature these may be drilled and tapped in the usual way.

If the armature binds when the bracket is screwed up tight and does not run perfectly free, yet is without shake, the seating is not true, and the feet require filing until all is correct.

Lastly, go over the whole casting with an old file, and take off all fins of metal and rough places, especially where the wire will be wound. This finishes the fitting proper of the machine, which may be given its first coat of enamel while the armature core is being prepared for winding.

Both armature and field-magnet require insulating

thoroughly before commencing the winding, to prevent the covering on the wire from coming into contact with metal. Too much care cannot be bestowed on this vital part of the work. Brown paper, although sometimes used for this purpose, is not reliable; tape soaked in shellac is better, but not so easy to handle. The best material is thin vulcanised fibre sheet $\frac{1}{64}$ in. thick, which can be made to lie neatly in sharp angles

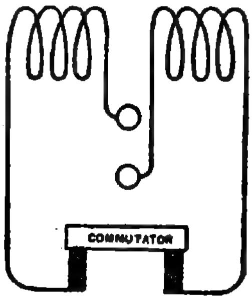


Fig. 86.—Winding Diagram

by cutting half through at the back with a sharp knife, as when bending up cardboard models.

The armature requires two end discs the same shape as the core discs, as many channels of fibre bent up to shape as there are slots, and also two extra strips covering the bare shaft at each end of the core.

Winding and wiring data are given in Table B, from which quantities and gauges of wire required for each of the three sizes of machines can be ascertained. Figs. 82, 83 and 84 show clearly the order of winding and connecting the coils, but to avoid complexity one turn only per section is shown; in practice, each

section will, of course, consist of several turns, as indicated in the table. Fig. 86 shows the direction of winding of the fields and connections to terminals and commutator.

TABLE B.—WINDINGS AND INPUT.

	F. M. Windings.	Armature Windings.	Input.	
			Volts.	*Amperes*
No. 1.	176 turns No. 22 s.w.g.	105 conductors per slot No. 26	4	1·5
No. 2.	252 turns No. 20 s.w.g.	66 conductors per slot No 24	6	2·5
No. 3.	274 turns No. 16 s.w.g.	48 conductors per slot No. 22.	8	4

If the proper sequence of winding is followed closely, no mistake or failure can occur. Note that each section is wound in the same direction, the ends being twisted together temporarily. When all the slots are full, these ends are finally and permanently connected up in this order: Join the starting end of one section to the finishing end of the next section all round the armature, and carry each junction so formed to one commutator segment—not that immediately in line with the junction, but one-quarter of the circumference in advance.

It is as well to allow full length to the connections at first, as this gives a little latitude for final adjustments in the position of the commutator, which may be slightly twisted either way to note if the running of the motor is improved thereby. This is necessary

owing to the brushes being fixed. The commutator is therefore made adjustable to a slight extent, so that its best position can be ascertained from trial, when it is firmly screwed up and the connections shortened, if necessary.

It may be mentioned that the winding of a drum armature with any number of slots can be carried out in exactly the same way as shown in the illustrations, remembering that the pitch or spacing of the conductors is equal to the half diameter less one slot, that each section fills one-half of the slot, and that each succeeding section commences in the slot just previously half filled, starting on the opposite side.

After winding, give two or three good coats of shellac varnish, and finish off the ironwork with enamel.

CHAPTER VIII

6-volt Traction Motor

THIS motor, which is shown in elevation in Fig. 87, plan in Fig. 87A and end elevation in Fig. 87B, may be made either of wrought iron, with stampings for the armature, or of cast iron for both fields and armature, the bearing brackets being castings, of course, in gunmetal.

For electric motors of the traction type wrought iron is very advantageous. The magnetic permeability of this metal is very superior to that of cast iron, and therefore with a given expenditure of electric current the strength of the field-magnets is enormously increased. The same applies to the armature, and in addition this part can be made up of standard wrought iron laminations built up on the armature spindle. Such an armature will stand a heavier current without heating up. The laminations prevent to a large extent the production of what are known as "eddy" currents, which represent so much wasted energy.

Of course, a casting for the field-magnets of the motor can be obtained from a pattern; but as this pattern involves a core-box for the tunnel, the amateur will find that it involves just as much labour to make the necessary pattern and clean up the castings as to saw the magnets out of raw material.

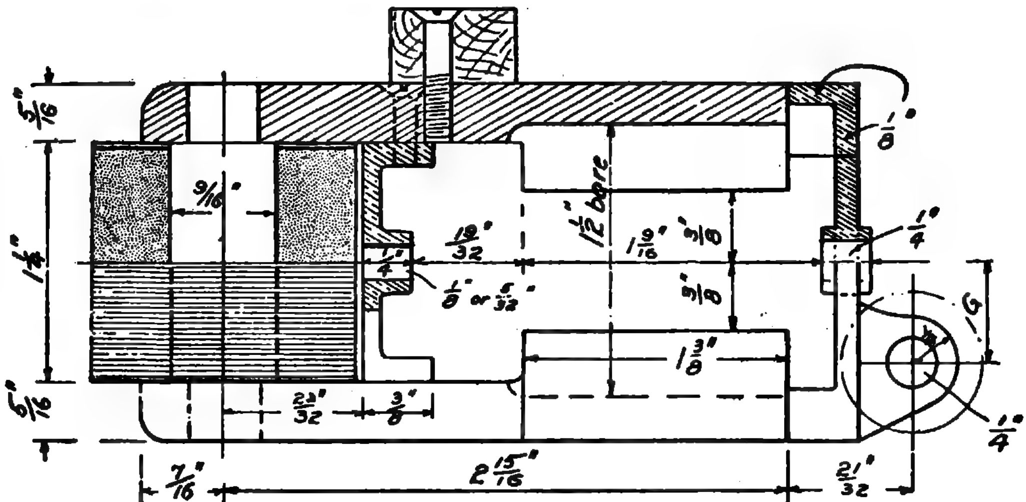


Fig. 87.—Elevation of Traction Motor

The field-magnets may therefore be shaped out of $1\frac{1}{2}$-in. by $\frac{5}{8}$-in. good wrought-iron bar. If good, soft, and homogeneous stuff like Swedish iron is not readily obtainable, a very mild quality of steel may be employed. The bar should be cut into $3\frac{3}{8}$-in. lengths, and then marked out as shown in Fig. 88. The limbs may then be sawn down to the reduced section, and to ensure accuracy the bars may be placed on the faceplate of the lathe after a small hole, say $\frac{1}{4}$ in. in diameter, for the winding core has been drilled. Then with the same setting the inside face may be machined true, and the winding core hole bored out to finished size.

The next operation would be to make the winding core out of Swedish iron bar to finish $\frac{9}{16}$ in. in diameter, shouldered down to $\frac{3}{8}$ in. in diameter at each end, as shown full size in the detailed illustrations of the motors (Fig. 87). The shouldered-down portions (or, at least, one) should be a driving fit on the magnet limbs. Before, however, this work is completed, to lighten the labour of boring out the tunnel the inside may be roughly chipped to the size marked out on the end. This work is optional, as the metal can all be removed in the lathe after the magnet is built up.

The method of setting it up on the lathe is shown in Fig. 89. The magnet limbs should be squared up if necessary, and bolted down on an angle plate, so that when the latter is level, that is, parallel with the bed, the centre line of each pole-piece when tried with a scribing block is exactly the same height above the lathe bed. When this degree of accuracy is

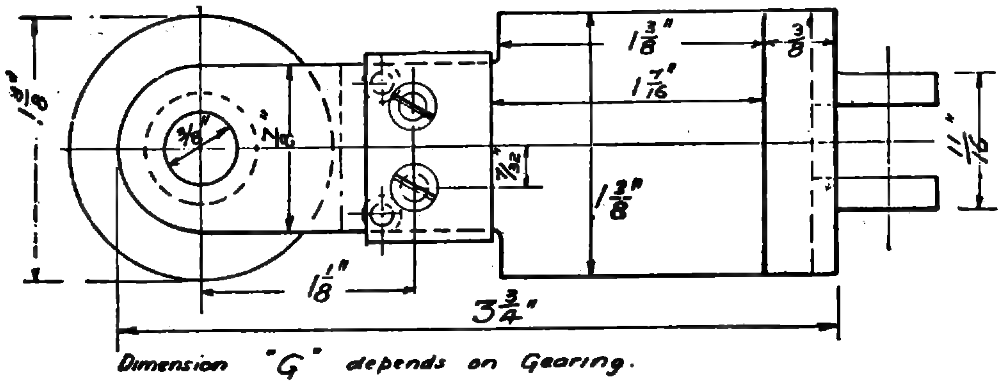


Fig. 87A.—Plan of Traction Motor

obtained, the bolts may be tightened up and the work proceeded with.

For wrought iron or mild steel the tool should be as shown in Fig. 90, with plenty of clearance to prevent the back rubbing on the tunnel during the boring process. The small sectional detail of the tool in Fig. 90 more clearly shows what is meant.

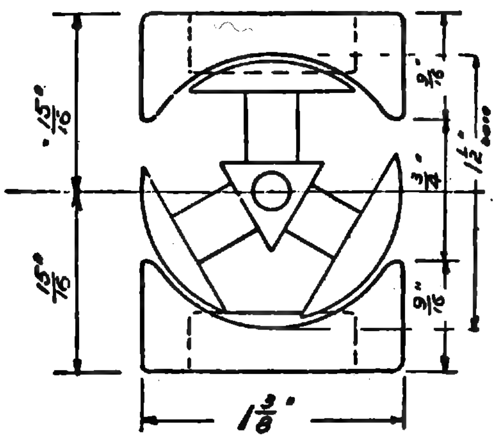


Fig. 87B.—End Elevation of Traction Motor

The bearing-plates are cast in gunmetal, or fashioned out of sheet material, the necessary bearing bosses and lugs being soldered on. The back bearing-plate, the one nearest the field-magnet windings, is quite a simple plate with a fixing flange top and bottom and a central bearing boss. It fits in between the limbs of the magnet, and is secured by two $\frac{3}{32}$-in. countersunk screws at each end. This bearing-plate may, if so desired, be fitted before the tunnel is bored,

as then it will be possible to drill it at the same setting. and ensure accuracy in the alignment of this bearing and the armature tunnel.

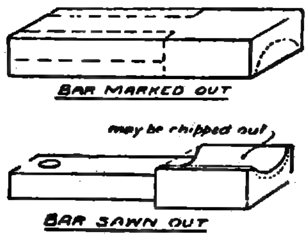


Fig. 88.—Field-magnet Limbs

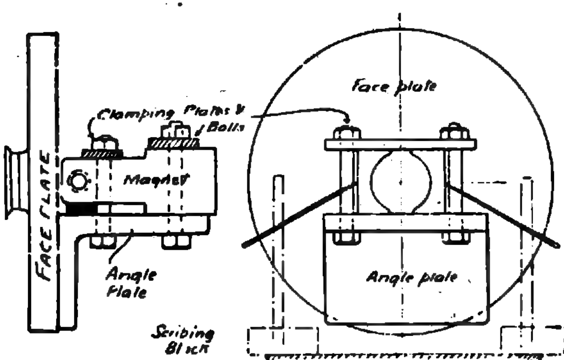


Fig. 89.—Setting up Field-magnet on Lathe for Boring Tunnel

The outer bearing-plate (Fig. 91) provides a certain amount of clearance for the projection of the end windings of the armature, and limits the length of the latter. In addition to the above and the central

boss, the outer plate also provides a transverse bearing for the support of the motor if used in traction work.

The bearing-plate being faced up, either with a file or in the lathe (the latter is a somewhat tentative suggestion, as it will be found difficult to set up), it may be drilled for the armature shaft, and the bosses faced with a rose cutter or pin-drill (Fig. 92). Then it may be drilled for the four $\frac{3}{32}$-in. fixing screws driven in the corners of the pole-pieces.

Following this comes the transverse bearing holes in the lugs.

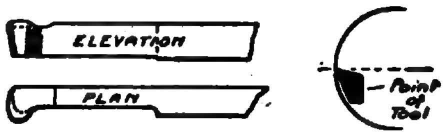


Fig. 90.—Boring Tool

As the field-magnet coil in a built-up wrought-iron motor can be "former wound," only one end of the winding core should be fixed. This is the end which drives the more tightly into the bored hole. The other end should be a good fit, and the parts may be finally secured with a small steel screw as shown in Fig. 93.

This completes the carcass of the motor, the work of filing up the parts to the required dimensions being done in accordance with the drawings at the respective and proper stages in the construction.

Where a one-piece casting is employed, the field core must be wound through the tunnel of the armature; this can be done between the lathe centres.

The other alternative (and the design of the parts is very well suited to this method) is to make the winding core of wrought iron and the limbs of soft cast iron. Only one simple wooden pattern will then be required This pattern will be the same shape as the bar in the lower sketch in Fig. 88.

Although the tripolar armature is, theoretically,

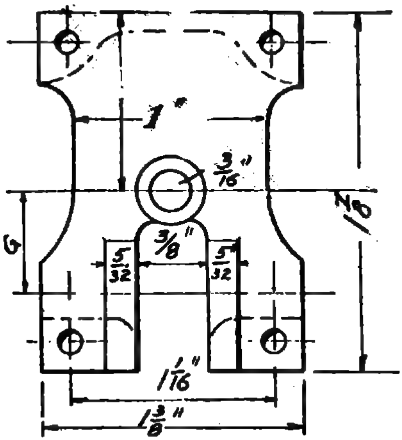


Fig. 91.--Outer Bearing Plate

not the most efficient, it has certain characteristics which often, in model electric traction work, make it the only one which can be employed without involving a high degree of skill. Without going into elaborate explanations, the inefficiency of the tripolar armature is due to the fact that the windings do not take up the best possible positions in the magnetic field. However, the tripolar armature is easy to wind, it is the simplest self-starting armature that can be

used, and, furthermore, stampings or castings are, in certain regular sizes, obtainable from most electrical and model dealers.

In the motor under discussion either one of two kinds of tripolar armature may be used, the cast or laminated, the latter being the better. The cast armature is usually employed where the windings have to be flush with the ends, and also where cheapness in construction is an important consideration. Fig. 94

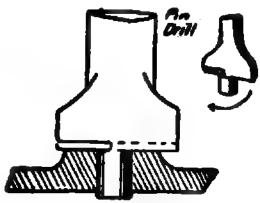


Fig. 92.—Facing Bearing Bosses

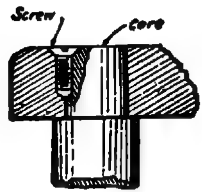


Fig. 93.—Fixing Limb to Core

is a diagram showing the difference which may be made in the shape of cast and laminated armatures.

Fig. 95 shows a suitable cast-iron armature; but it will be noticed the necessary checking-in of the winding cores is very slight—only $\frac{1}{8}$ in. at each end—as the design of the motor provides for the extension of the windings. In addition, the armature may be fully $1\frac{3}{8}$ in. long at the poles. A solid cast-iron armature can be fixed to the shaft by being drilled a driving fit for the shaft; but if a further security is required, either a screw may be fitted in the centre

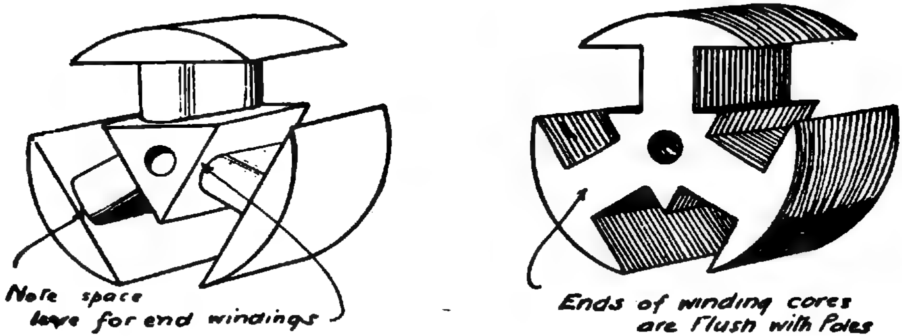


Fig. 94.—Different Shapes of Cast and Laminated Armatures

of one of the poles as shown in Fig. 96, or as an alternative a pin or a set-screw may be driven into the projecting boss at the ends as shown in Fig. 97.

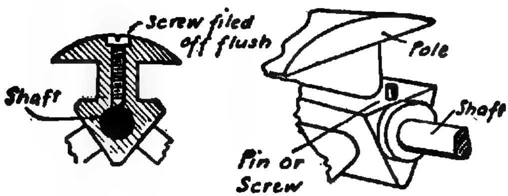
When fixed on the shaft and centred at one end, one end of the shaft may be held in a three-jaw chuck, and with the other one in the dead centre, light cuts may be taken over the pole-pieces, so as to reduce the armature to the required $1\frac{3}{8}$-in. diameter. Care must, however, have been taken to drill the shaft hole concentric with the other parts of the casting.

Nothing gives so much dissatisfaction and trouble in subsequent working as a badly balanced armature. Therefore, care must be taken to see that a good balance is obtained both mechanically and electrically; and after the casting is examined for general truth and soundness, and any excrescences removed from the surface of the poles with a suitable file, it may be held in the self-centering chuck for drilling. Before this latter operation is actually accomplished, any glaring inaccuracy can readily be observed and remedied by filing either one or the other of the poles.

A laminated armature requires different treatment. In this case the windings extend to the amount of their whole depth at each end. Therefore the armature cannot in the present motor be longer than $1\frac{5}{16}$ in.; indeed, it had better be $1\frac{1}{4}$ in. long rather than exceed the first-mentioned dimension. As the name implies, a laminated armature is built up of stampings of thin sheet-iron. The iron should be soft, of the best quality, and have greatest magnetic permeability.

In a small armature the stampings are, if necessary, flattened and coated with a shellac varnish partially to insulate them from each other, and in this way resist the longitudinal flow of "eddy" currents. Then they are threaded on the armature shaft, which, as shown in Fig. 98, is of special design, with a collar at one end and a clamping nut at the other.

The centre hole, which is usually provided in the stampings, should be a good fit on the shaft; and if it is not of the size chosen, the shaft will have to be



Figs. 96 and 97.—Cast Armature Fixing

turned down from a bar of sufficient diameter. If this has to be done, then the collar may be in the solid, and not a loose collar pinned on to a piece of commercial bright steel rod $\frac{3}{16}$ in. in diameter, such as is shown in Fig. 98.

When the armature stampings are in place and the clamping nut about to be tightened up, the stampings may be squared up and the nut screwed down. No further fixing should be required, and if the stampings are of good quality, they should run reasonably true on the shaft, any slight burr in the periphery being easily removable with a smooth file.

The winding core of the armature may then be

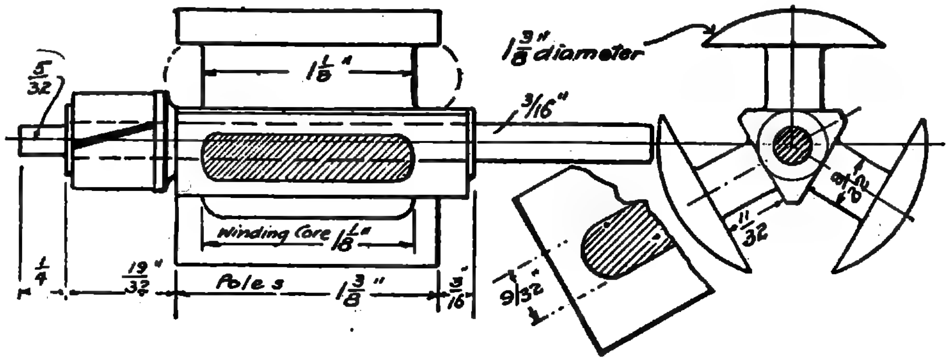


Fig. 95.—Suitable Cast-iron Tripolar Armature

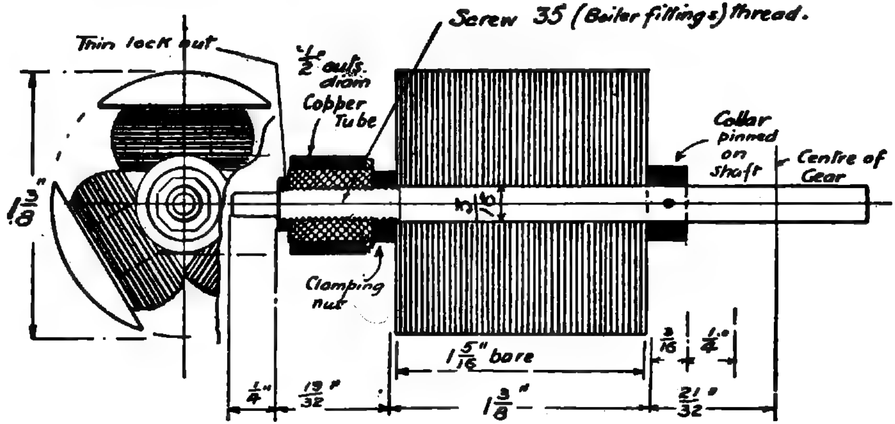


Fig. 98.—Laminated Armature

cleaned up preparatory to the winding, any burrs or spikes which might pierce the insulation of the wires wound over them being carefully removed, and, as far as possible, the ends of the cores should be rounded off to prevent any similar electrical failure. Of course, this rounding off cannot be great, as in the case of the solid-cast armature.

In Fig. 87 the back (inside) bearing is dimensioned for either a $\frac{1}{8}$-in. or $\frac{5}{32}$-in. journal. The laminated

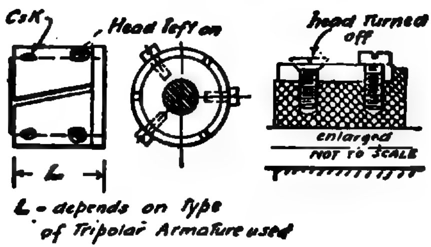


Fig. 99.—Making the Commutator

armature, where a $\frac{3}{16}$-in. diameter shaft is employed will necessitate the adoption of the smaller dimension

The commutator may be built up in a variety of ways. The simplest method is to bore a piece of ebonite or vulcanite fibre for a driving fit on the shaft, or else to a tapping size to suit the thread cut on the shaft (see Fig. 98). This insulating bush is then turned with a slight flange at one end (to keep the metal surface from touching the armature), to suit a piece of thick brass or copper tube.

This tube is then driven on, and six screws as shown in Fig. 99 driven into the insulation; but not

in any circumstances, into the hole for the shaft. The outer screws should be countersunk; but the inside ones may have projecting heads, and be afterwards used for attaching the windings to the commutator segments. The countersunk screws should not be fully countersunk into the metal tube. The tube may then be sawn into three equal segments, as indicated,

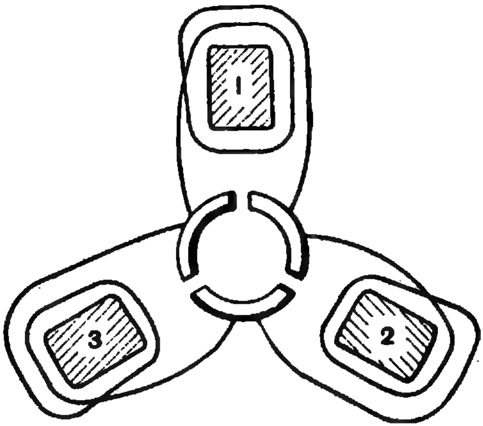


Fig. 100.—Armature-winding Diagram

preferably by an inclined cut. The metal should be just separated, and that is all.

The commutator may then be put in its place with the three saw cuts opposite the respective poles.

A diagram (Fig. 100) showing the direction of the armature winding and commutator position is given. This method of winding is known as the closed-coil system, and is much to be preferred to the arrangement common to most toy motors, in which the

starting ends of each coil are connected together, and the finishing ends to the nearest commutator segment. In the diagram the winding cores are shown in section and numbered 1, 2 and 3 respectively. As will be seen, the beginning and end wires of each adjacent coils are joined together and attached to a segment between those coils.

The brush gear for the traction motor under discussion is very simple. It consists of two sheet-metal brushes, clubbed at the ends which bear on the commutator, screwed to an insulating block of vulcanite

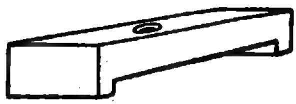


Fig. 101.—Insulating Block for Brushes

fibre, ebonite, or hardwood (for preference, either of the first two materials), which in turn is fixed to the uppermost limb of the field-magnet. In Fig. 87 this insulation is shown fixed to the field-magnet with two $\frac{1}{8}$-in. steel countersunk screws. However, if the block is made as shown in Fig. 101, with a lip or flange at each end to fit over the magnet limb M (Fig. 102), only one screw will be required. The brushes should be about $\frac{1}{32}$ in. thick and sheared out of hard springy brass sheet.

The blocks of metal K (Fig. 102) at the ends may be of brass or copper, and should be soldered on. When new they should be filed to a smaller radius than that of the surface of the commutator, so that

the points bear on the commutator rather than the middle. This is important to the success of the motor, as unless the brush contact bridges the slots in certain positions of the armature it will not start readily.

There are two methods of fixing the brushes to the insulating block, shown respectively on the right-hand and left-hand sides of the full-size sketch

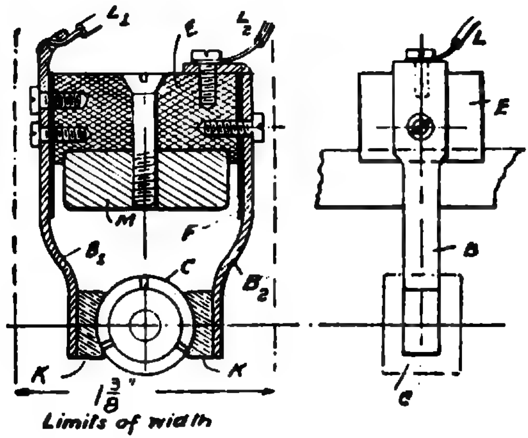


Fig. 102.—Brush Gear Complete

(Fig. 102). The brush B_1 is shown fixed with two screws into the side of the insulating block, the connecting wire L_1 being threaded through a hole in the top of the brush and soldered. The right-hand brush B_2 is attached with a screw in the side and one in the top, the latter being used as a connection for the looped end of the lead L_2. The strip F is a piece of insulating material (thin sheet fibre), which is intended to prevent the brush touching the field-

magnet and causing a short circuit through the motor to the return (running) rails.

This completes the motor except for the windings. For ordinary purposes and pressures of 4 volts to 6 volts, the field-magnets may be wound with No. 20 cotton-covered or No. 18 silk-covered wire, and the armature with either No. 22 cotton-covered or No. 20 silk-covered wire. These windings should be connected in series.

CHAPTER IX

60-watt Simplex Dynamo or Motor

The dynamo or electric-motor shown by the accompanying photographic reproduction is an interesting piece of mechanism, and one that will repay the maker for his time and trouble, as a number of absorbingly interesting experiments are possible with even a small machine.

Unsparing as the efforts of the maker may be, however, unstinted patience and skill will not make a satisfactory machine out of a badly designed set of castings, and the idea so prevalent among amateurs that an efficient dynamo or motor can be built out of any old "scrap" and oddments, is one that it is best to discourage at the outset. Leave the actual designing of the machine to the more experienced workers, and refrain from experimental attempts to "hit off" by some freak design something that requires much experience, training, and skilled investigation to accomplish.

To the reader who intends building his first dynamo or motor, therefore, the best advice that can be given him is to buy a set of castings and parts ready made, or to copy some proved machine, and not worry about designing it at all.

There is an illimitable choice to suit all tastes and pockets. All designs are not equally efficient, nor are all castings equally good, however, and a little discretion and help is needed when the amateur makes his initial purchase.

Too often good points in design are sacrificed to cheap production; but in such cases the extra labour and time occupied in fitting greatly outweighs the initial saving in the outlay.

The majority of small motors and dynamos sold for amateur construction are too lightly built in the armature shaft and bearings to be ever really satisfactory, whereas a little more forethought on the part of the designers would have cost no more in the first place, saved work in the fitting, and increased the lifetime of the machine very greatly indeed.

With these points in mind, the writer has tried to study the interests and at the same time the workshop equipment of the reader in designing the machine here illustrated.

The first consideration of all is simplicity. There is no object whatever in building a complicated piece of mechanism when a more simple construction will do the same work. So long as the dynamo is thoroughly reliable, efficiency, although important, is to the amateur a secondary matter; and stability, perhaps, may be given the third place in order of importance. These items are all embodied as far as possible in Fig. 103, which shows the completed dynamo or motor.

In general design it is a type known as "Simplex"

or "C-type," one of the simplest forms, since the field-magnet is all in one piece, and no work is therefore required in jointing it together. Moreover, the

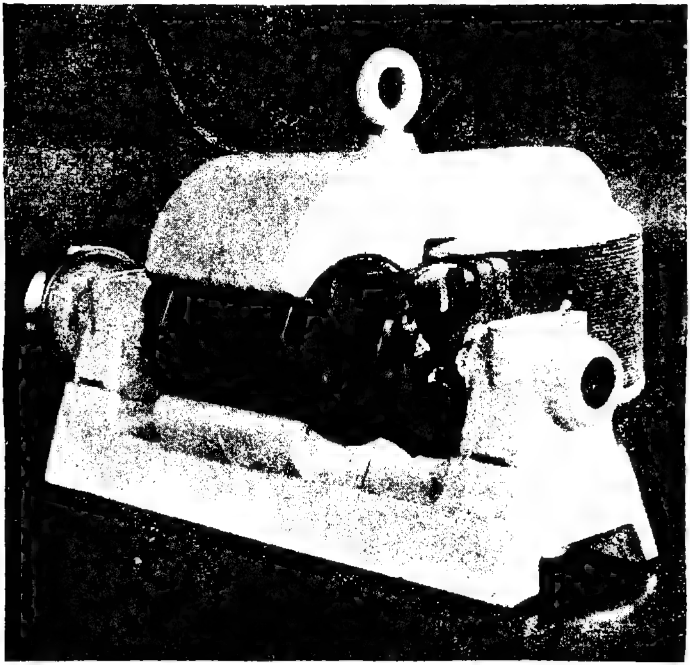


Fig. 103. Photograph of 60-watt Dynamo or Motor

winding is exceedingly simple, there being only one coil. The bearings—the weakest point in all model machines—are both here exceptionally substantial, and so designed that little or no hand fitting is required at all. The other features are all equally simple, and will be described in detail.

It will be evident from a study of the drawings that the whole of the work ought to be well within the ability of the amateur making his first attempt in this direction, provided he is willing to spend a reasonable amount of care in following out the instructions that will be given.

Let it be clearly understood, however, that the work calls for the use of a lathe, and it would be folly to attempt building this dynamo without the assistance of, say, a 3½-in. lathe, as the greater part by far of the fitting is in the nature of lathe work.

Before starting instructions on fitting, a full specification of the machine will first be given, then a list of the various uses to which it can be put, and lastly a detailed list of items required for the production of the complete article.

In its technical description this dynamo or motor would be known as follows: Simplex bipolar type with cast-iron field-magnet in one piece with radial bearing seats. Bearings of the self-oiling ring lubricating type, self-aligning with radial seats. Armature of the laminated slotted drum pattern, with steel shaft running in cast-iron bearings. Commutator of the disc type, with copper gauze plunger brushes and adjustable brush rocker.

As to the capabilities of this machine, it is equally serviceable either as dynamo or motor, and requires no alteration made in the winding or the adjustments for either purpose beyond a little movement in the brush rocker. The output capacity as a dynamo is

60 watts for continuous running; but this can be largely increased for short periods.

A convenient winding, and the one chosen for the present purpose as an all-round useful figure, is 10 volts 6 amperes, shunt-wound. This will serve for lighting lamps, charging accumulators, electro-plating, driving electric models, making magnets, etc., and many other experimental purposes where more current is required than could be supplied by batteries. To develop its full output as a dynamo the machine requires driving at 2,400 revolutions per minute, and will take about $\frac{1}{8}$ brake horse-power.

The maximum number of lamps it will light for continuous running is six of 10 volts, 10 c.p. each; while as a charging dynamo it will deal with as many as six 4-volt cells of 20 ampere-hour capacity at a time.

As a motor, it will work very efficiently with current supplied from accumulators of 4 volts upwards. It will only run slowly, of course, from 4 volts; but full speed and power will be developed with 10 volts or 12 volts, sufficient to drive a 12-in. ventilating fan, a large sewing-machine, small grinding and polishing wheels, or any other devices not calling for more than $\frac{1}{12}$ b.h.p. to $\frac{1}{10}$ b.h.p.

The full set of parts required to complete the machine is given on the following page.

LIST OF MATERIALS, &c., FOR 60-WATT SIMPLEX DYNAMO

Number or Quantity.	Material.	Part.
1	Cast-iron	Field-magnet
2	Ditto	Bearings
1	Cast brass	Pulley
1	Steel	Armature shaft
100	24 g. iron sheet	Armature stampings
1	Fibre disc	Commutator
1	Brass ring	Ditto
6	5 B.A. brass screws	Ditto
1	Fibre sheet	Brush rocker
2	Brass tubes	Brush holders
2	Brass springs	Ditto
2	Copper gauze strips	Brushes
1	Steel	Eyebolt
2	0 B.A. steel screws	Bearings
1	4 B.A. iron screw	Pulley
1	Brass clamp nut	Armature stampings
1	Brass clamp nut	Commutator
2	Brass oiling rings	Bearings
2	4 B.A. brass screws	Brush holders
2	4 B.A. brass nuts	Ditto
2	4 B.A. brass washers	Ditto
1	4 B.A. brass screw	Brush rocker
2	5 B.A. brass screws	Ditto
1	Sheet insulation	Armature and fields
5 oz.	No. 22 d.c.c. copper	Armature
2 lb.	No. 21 ditto	Fields

The machining and fitting processes are all very simple, and quite within the capacity of a 3½-in. lathe. It is best to start work on the field-magnet casting, following on with the armature, bearings, commutator, and brush gear, all in the order stated. No part of the winding must be attempted until all the fitting has been done, or the insulation would be very liable to get damaged.

Beginning with the field-magnet casting (Fig. 104),

the first thing to be done to it is to true up the underside of the base, if it needs it, in order that it stands firmly and without rocking when placed on a level surface, such as the bed of a lathe. If a small planer or a shaping machine is at hand, this is quite a simple process, the casting being mounted on the table upside down, and the lightest cut that will level the base taken across it. If no shaper or planer is available, a little careful filing will accomplish the same end, as if the castings are good there will be very little to come off them. Do not put a new file on the hard, rough skin of the casting, or it will be spoiled quickly. Use an old rough-cut file to get down to the bright metal, and finish with a better file. Try the work frequently on a flat table until the "rock" is all taken out, removing as little metal as possible.

An alternative way of facing down the base is to glue a sheet of No. 2 emery-cloth on a flat board, and using plenty of oil on the surface, grind down the base by long, slow strokes under heavy pressure by hand.

The next operation is to bore out the tunnel for the reception of the armature, and to machine the bearing seats. The casting is so designed that all these processes can very simply be carried out at one operation on a self-acting lathe, by mounting it on the saddle of the slide-rest, and causing it to traverse the lathe bed at the same time a cutter bar of suitable size is rotating between the centres.

The easiest way for the amateur to set up the work accurately is first to turn a round cylinder of hardwood

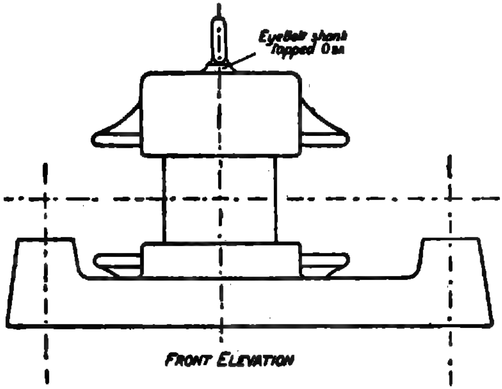


Fig. 104.—Front Elevation of 60-watt Dynamo

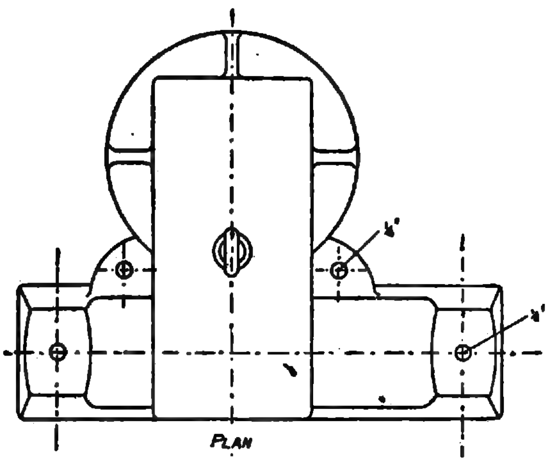


Fig. 104A.—Plan of 60-watt Dynamo

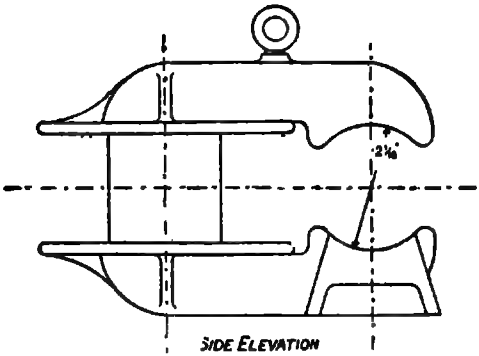


Fig. 104B.—Side Elevation of 60-watt Dynamo

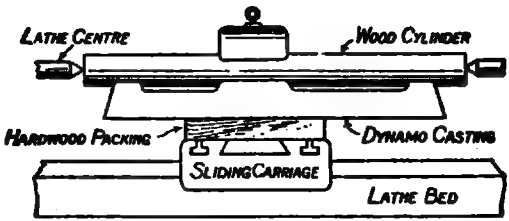


Fig. 105.—Fixing Field-magnet for Boring

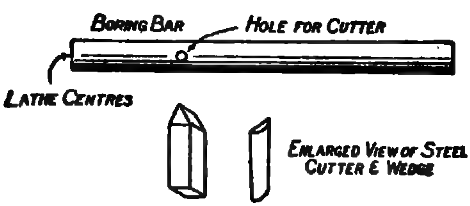


Fig. 106.—Boring Bar and Cutters

long enough to reach from end to end of the two bearing seats and of such diameter as to drive easily between the pole-pieces, which in their rough state before machining are about $1\frac{7}{8}$ in. in diameter. Leave the centres on which the wood cylinder was turned in at the ends, and when the wood has been driven into position in the casting, the whole structure is mounted between the lathe centres, with the base over the saddle of the slide-rest (see Fig. 105). This will settle once for all the thickness of packing between the saddle and the dynamo base, and the position in which it should be bolted to the slide-rest. Use only metal or hardwood for the packing, or the pressure of the bolts will throw it out of truth again when tightened up. After fixing, test again with the lathe centres for accuracy, and when correct drive out the wood cylinder, leaving the casting firmly attached to the slide-rest ready for boring.

The tool used for boring is very simple, consisting of a length of iron or mild steel round bar $1\frac{1}{4}$ in. in diameter, with a $\frac{5}{16}$-in. cross hole drilled through the centre for the insertion of a steel cutter, which is either wedged or screwed into position. The depth of the cut is regulated by the amount by which the tool protrudes from the bar; the bar itself does not touch the work, so that it need not necessarily be turned, and it does not matter even if it runs slightly out of truth, provided the centres are good at the ends. A piece of $\frac{1}{4}$-in. square tool steel makes a good cutter, and boring bar and tool are shown separately in Fig. 106. The point of the cutting tool is shaped

exactly like the ordinary facing tool for metal turning in the lathe.

With the back gear on, and the self-acting traverse set as though for cutting a screw of about thirty-two to the inch, a light cut is now taken across both bearing seats and the armature tunnel. If possible, try to get underneath the hard skin of the casting with the first cut, otherwise frequent tool sharpening will be found necessary. The cut must not be so deep, however, as to risk disturbing the position of the casting, since it is essential that the same cut is taken right through from end to end without alteration in setting either of work or tool, otherwise no reliance can be placed on the bearings coming accurately into line presently and holding the armature exactly central in the bore.

The finished diameter of the armature bore is to be $2\frac{1}{16}$ in., and the radius of the bearing seats will, of course, be exactly one-half of this, or $1\frac{1}{32}$ in. The last cut should be very fine, hardly more than a scrape, and the tool should be ground to a rather broad rounded point with an oilstone edge. This will leave a nice finish on the work.

There is little else to do on the field-magnet casting, except to bore two holes for the fixing bolts which hold the machine to the ground, and two for the set-screws which attach the bearings. Their size and position are clearly shown in the illustrations. One more hole is drilled in the centre of the boss on the top of the casting, and tapped with a No. 0 British

Association thread to take a small eyebolt for lifting purposes.

Lastly, go over the whole casting with an old file, especially in the winding space between the flanges, and remove any sharp pins and roughness that might penetrate the insulation of the wire or otherwise spoil the finished appearance. This completes work on the field-magnet, and the armature is the next to take up.

The mild-steel shaft is first centred carefully, so

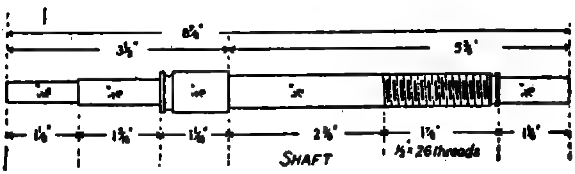


Fig. 107.—Armature Shaft

as to run as true as possible, mounted between the lathe centres, and rough-turned to the dimensions given in Fig. 107, leaving all sizes $\frac{1}{16}$ in. full for the present until the bulk of the metal has been taken off. The shaft is nearly sure to spring slightly during the rough turning, and the over-size allowance made ensures there being sufficient metal for finishing to exact dimensions later.

When roughed up to size all over, proceed to turn up the largest step on the shaft forming the shoulder for the stampings, and also that part of the shaft which passes through the armature core. These can be finished and polished, and the thread cut ready for assembling the stampings. The latter (Fig. 108) are

threaded on the portion prepared for them, with all the slots nicely in line, and screwed up firmly by means of the hexagon brass nut. Hammer them up if necessary until the nut will turn no tighter and it is impossible to twist the stampings round on the shaft by hand. The more carefully the slots are lined up

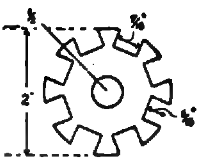


Fig. 108. Armature Stamping

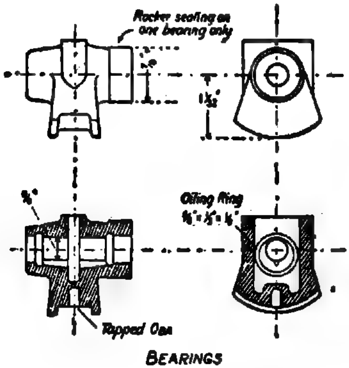


Fig. 109.—Bearings

the less work will there be in filing them out afterwards.

Two shallow grooves $\frac{3}{16}$ in. wide and $\frac{1}{16}$ in. deep are turned in the core $\frac{1}{4}$ in. in from each end, to receive the binding wire later on which holds the windings in position. If any difficulty is experienced here through the teeth breaking out, some hardwood strips may be fitted in the slots temporarily.

The end of the nut which clamps the stampings

must be nicely squared, as this forms a shoulder against which the commutator presently bears.

Try the armature in the lathe centres again after fixing the stampings, and it will most likely be found to have sprung the shaft slightly out of true. Fix a piece of hardwood in the slide-rest, and, turning the armature round with the fingers to find which is the high side, feed the slide-rest forward, forcing the shaft to spring until it runs quite true again. Not until then should the remaining "steps" on the shaft be finished off, or they will not be truly concentric with the stampings.

To ensure getting the shaft diameters of the correct size, a good plan is to drill and ream a hole in a piece of thick sheet brass, and use this as a gauge.

The two bearings (Fig. 109) are alike except that one has a seating at one end for the brush rocker, while the other has not. They must be mounted to run true in a centering chuck, and a drill cutting $\frac{1}{64}$ in. under $\frac{3}{8}$ in. run through them, holding the drill by means of a lathe dog or vice, and feeding it up by the tailstock centre. Take them out of the chuck, and finish the holes by passing a $\frac{3}{8}$-in. reamer through them by means of a tap wrench. This leaves an excellent smooth and parallel hole, in which the steel shaft will run nicely if kept well oiled.

The oiling is done automatically by a small brass ring, which is dropped into the slot in the top of the bearing, and which hangs on the shaft and rotates with it. The underside of the ring dips into the oil reservoir below, and so carries oil to the shaft to an extent

proportionate to its speed. At the end of the bearing will be seen two slight recesses, into which surplus oil is flung off by the grooves turned in the armature shaft. To prevent this overflowing a narrow oil duct is filed at the bottom on each side, communicating with the centre reservoir, so that the oil is used over and over again.

When the bearings have been drilled and reamed for the shaft, they require to be mounted on a mandrel between the lathe centres, and finished thus, so that the seatings where they fit on the field-magnet, and the rocker seating, are both perfectly true with the central hole.

If the bearing seats are turned to a radius of $1\frac{1}{32}$ in. they will be found to fit exactly to the curve of the field-magnet casting, and will only fit in one position; hence they cannot help coming into line, and the tiresome and tedious process of hand-filing, generally necessary in small machines to get the shaft to run free, is thus entirely avoided.

The bearings are fixed to the radial seats on the field-magnet with a single screw in the bottom. This is shown in Fig. 109, and in drilling and tapping for these take care not to break through into the oil chamber, as leakage of oil is pretty sure to occur if this happens.

Try the shaft in the bearings when they are finished, and it will be found to run freely and the armature stampings exactly central in the tunnel, if all the foregoing work has been done as instructed.

The pulley (Fig. 110) is a perfectly simple piece

of brass turning, and needs no special comment. Grip the casting in a self-centering chuck, bore the centre, and rough turn all over as far as the tool will reach. Then take it out of the chuck and drive on to a mandrel, taking a light finishing cut while running on its own centres, as this is the only way to ensure it being perfectly true. It is highly advisable when turning up work on small mandrels to use the standard hardened-steel mandrels sold by toolmakers. The

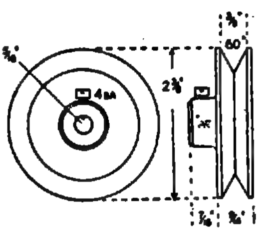


Fig. 110.—Pulley

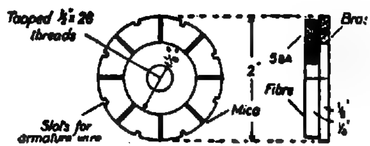


Fig. 111.—Commutator

amateur article made from soft steel too easily bends, and it is annoying to find the work all out of truth as a consequence when transferred from the mandrel to its own shaft.

The disc commutator (Fig. 111) is a very simple piece of work, much easier for the amateur to make up than the barrel type. It consists of a brass ring screwed on to a fibre disc, and divided into eight segments by saw cuts, leaving each segment insulated thus from the rest. Mount the brass ring in a centering chuck, and turn the inside hole and one

face perfectly true. If there is a division plate on the lathe, mark off sixteen equal portions, eight of which will be for screws, and eight for the saw cuts. A centre line is also turned on the ring before it is removed from the chuck. Mark the eight screw holes with a centrepunch drill to tapping size for a No. 5 B.A. thread, and tap one of them only for the present.

Now prepare the fibre disc by chucking a piece of $\frac{3}{8}$-in. fibre sheet, facing one side and leaving a shallow spigot of about $\frac{1}{16}$ in. to fit the central hole in the brass ring. Drill the centre hole in the fibre, and tap $\frac{1}{4}$-in. by 26 threads perfectly square with the face. Now take it from the chuck and lay it on the bench face side upwards, and fit the brass ring over the spigot. With a small scriber mark the position of one of the holes on the fibre, drill it clearing size for a No. 5 B.A. screw, and countersink the back, so that the screw sinks just beyond flush. Replace the brass ring and insert the screw.

The brass ring now serves as a template, by which the seven other holes are drilled for the screws, ensuring thus that they come exactly in the right places. Tap the remaining holes in the brass commutator ring, enlarge and countersink those in the fibre, and screw the two together firmly. Now saw through the face of the brass ring where the intermediate lines are scribed until the saw just cuts into the fibre back, and there will be eight segments securely held and all insulated.

To prevent the saw cuts from wearing out the

brushes too quickly, it is best to drive in some tightly fitting strips of mica, fastening them with a drop of shellac varnish. When quite dry mount the whole on the shaft, screwing it against the shoulder formed by the nut clamping the stampings, and lock it in position with a thin ½-in. by 26-thread nut. The edge and two faces are then easily turned true, using the shaft as a mandrel. Use a sharp tool and run the work at a high speed, polishing with fine emery-cloth and oil.

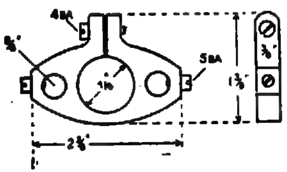


Fig. 112. - Brush Rocker

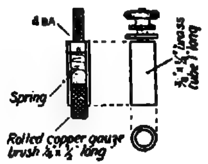


Fig. 113. - Brush Holders

In the illustration of the commutator (Fig. 111) it will be seen that the brass ring is allowed to project a little beyond the fibre, and is notched in each segment to receive the armature wires which are afterwards soldered in.

Fig. 114 shows the armature core, shaft, commutator, and pulley assembled.

The brush rocker is made of ⅜-in. fibre sheet, filed nicely to shape as in Fig. 112. The centre fits on the flat seat turned at the end of one of the iron radial bearings, round which it can be rotated to a certain extent to allow for the difference of brush position

between dynamo and motor. A pinching screw at the top closes in the rocker, and holds it firmly in the rocker seating. The holes for the brushes must be drilled carefully at the correct distance apart, and square with the rocker, or the brushes will set badly on the commutator.

The brush holders (Fig. 113) are very easy to build up, as they consist of two plain pieces of brass tube, and into one end of each is soldered a No. 4 B.A. brass

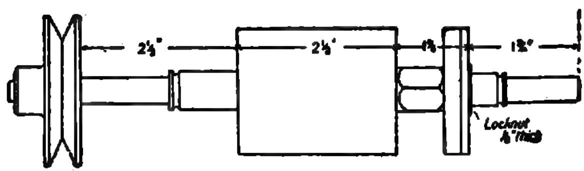


Fig. 114.—Armature Details

screw-head, leaving the threaded part projecting to form the terminal screw. A milled nut and washer on each serves to attach the wires to the outer circuit. The brush holders should be a sufficiently good fit in the fibre to hold themselves; but for security two small brass screws are tapped into the rocker ends, and pinch the holders when they have been set in the correct position. These two screws also serve for the attachment of the two ends of the field-magnet winding.

The correct position for the brush holders is when their ends clear the face of the commutator by $\frac{3}{32}$ in. The brush springs are of No. 26 phosphor-bronze wire 1 in. long when extended, and the brushes consist of

a ½-in. strip of sixty-mesh copper gauze tightly rolled up into a cylinder of such size that it will slide just freely in the barrel of the brush holder.

There is practically nothing more to do to the fitting, and the machine may have a preliminary coat of paint before starting the winding. If an "exhibition finish" is desired, the first or primary coat should consist of a thin flat grey paint put on after all grease or dirt has been removed carefully from the ironwork; this enables the subsequent coats to key on properly.

The next coat should consist of a filling composition, such as "Ferrodor," which when hard can be rubbed down carefully with pumice or glasspaper. It can be mixed thin or thick as desired, and used as a kind of putty to fill holes or defects. With one or two coats of this, well rubbed down in between, a perfectly smooth surface is obtainable even on a rough casting and a final coat of good enamel put on with a soft brush in a room free from dust will ensure a beautiful finish.

The worker who is unaccustomed to winding dynamos will find it best to start with the field-magnet, as the experience gained in handling the wire on this simple and straightforward job will give him confidence when he attacks the armature.

The preliminary necessity to all winding operations is "insulation." No wire must be wound direct on to the bare metal, because even though it is cotton-covered, and therefore insulated to a certain extent, the covering is not mechanically strong, and might

get damaged unless extra protection is provided where it comes against the framework of the machine.

The three most useful materials for insulating purposes are (1) vulcanised fibre, a strong, dense material easy to work, and very useful for insulating washers, bobbin ends, etc.; (2) presspahn sheet, a material like stout brown paper or cardboard in various thicknesses, useful more especially for lining wire spaces and armature slots; and (3) adhesive tape, which is impregnated with a sticky insulating compound, causing it to adhere to the work to which it is applied.

For the field-magnet insulation a piece of $\frac{1}{16}$-in. fibre sheet and $\frac{1}{50}$-in. presspahn will be required. Cut three circular washers of the latter and one of the former, each measuring 4 in. outside diameter and $1\frac{13}{16}$ in. inside diameter. Also a strip of presspahn $2\frac{1}{4}$ in. wide by $5\frac{1}{2}$ in. long will be needed. This is cut half through with a sharp knife $\frac{1}{4}$ in. in from each edge along the long sides, and notched with scissors at intervals of $\frac{3}{16}$ in. as far as the knife cuts. This enables the two margins to be turned up as right-angled flanges, and the whole bent round the limb of the field-magnet in circular form.

The washers have a radial cut made on one side into the centre hole to allow them to be sprung over the field core, and are assembled in the following order: First the flat strip with the flanges, which should fit snugly into the angles; at one end place one presspahn washer, and at the other end two presspahn washers interleaved with the $\frac{1}{16}$-in. fibre washer

The radial cuts must be arranged so that they do not come together. The whole arrangement is shown in Fig. 115, where the washers are separated to show their arrangement. The object of the fibre washer is to provide a way in for the starting end of the winding, and at the same time afford protection from the iron on the one side and the layers of field wires on the other.

The most convenient method of carrying out the

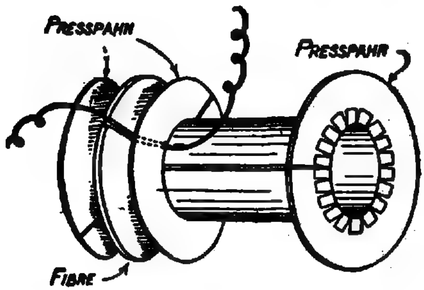


Fig. 115.—Arrangement of Field-magnet Insulation

winding is to make two centres in the casting and mount it in the lathe, with the back gear in so that the casting revolves slowly. The wire can then be fed on evenly by hand with a fair amount of tension and as neatly as possible, in order to get on the maximum number of turns.

A careful and patient winder will manage to get on twenty-four layers of No. 21 S.W.G. d.c.c. copper, each layer containing about forty turns of wire. The last few layers may not be quite so even as desirable, and in order that the work may look as creditable as

possible it is a good plan to cut a strip of presspahn sheet the same width as the inside of the flanges and long enough to go once round the winding, and wrap this round the coil before starting on the last layer. This gives an even surface, and the neat appearance of the outside layer well repays the trouble taken. To finish off, wind in a piece of stout thread with the last few turns, and use the ends to tie down the final turn.

A couple of feet or so of extra wire should be left both at the starting and finishing ends, and this coiled

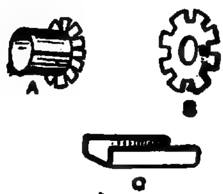


Fig. 116.—Armature Insulation

closely round a ¼-in. rod to form a spiral which can be stretched slightly when connecting up to the brushes. The last layer of wire needs coating with good shellac varnish to preserve it from damp and dirt. Two or three coats are advisable.

The armature insulation consists of the separate items shown in Fig. 116, namely, two cylindrical pieces A with flanges fitting over the ends of the armature shaft close up to the core, two washers B cut to the shape of the stampings, placed outside the flanges and close against the armature core, and eight channels C nicely fitting the slots, but ⅛ in. longer than the core, so as to project just beyond it at each

end. The armature is now entirely clothed with insulation wherever the wire comes, and this insulation must be most carefully preserved, as should it get damaged and the wire come into contact with the iron, it will probably "leak" and the machine refuse to work. To safeguard against this as far as possible, the extreme edges of the slots should have been previously rounded off with a file to avoid cutting through the insulation where the wire presses on them.

Mount the armature between the lathe centres, with the commutator to the left hand, and wind with No. 22 S.W.G. D.C.C. copper, with forty-eight conductors per slot in two sections of twenty-four turns each. There will be three layers to each section, each layer consisting of eight turns.

The method of winding is briefly as follows, space forbidding a very detailed description.

Those who wish for further guidance should consult the "Work" Handbook "Dynamo and Electric-motor Building," in which the whole process is given and illustrated by photographs.

The main thing to remember is that each section of the winding must be wound in the same direction, each consist of the same number of turns, and all wires pulled tightly and evenly round the core to prevent slipping, though with not sufficient force to cut through the insulation.

The span of the coils is in all cases one slot short of the half diameter; that is, slots 1 to 4 inclusive, and each section of the winding half fills a slot. Remember that each subsequent section begins in

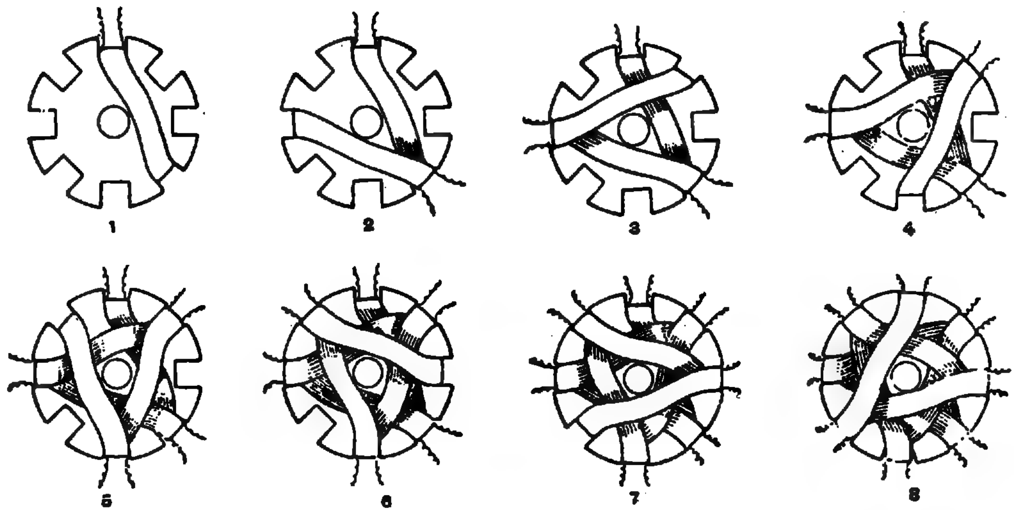


Fig. 117.—Eight Stages in Armature Winding

the slot previously finished, and on that side which has no free ends of wire in it. The starting end of each section should be knotted or otherwise marked to assist when connecting up, and the finishing end is twisted to the starting end temporarily.

The order in which the coils are put on will be gathered from the set of eight sections shown in Fig. 117, from which it will be seen that each slot contains two sections and two ends of one section. These two ends are reconnected by carrying the start

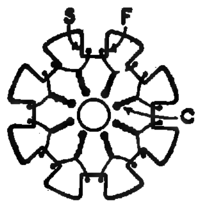


Fig. 118.—Connections from Armature to Commutator

of one to the finish of the next pair of ends in an adjacent slot all round the armature, resulting in eight junctions (see Fig. 118, where S is the starting end of the section, F the finishing end, and C the commutator segments). Each junction is then taken down to the nearest commutator segment and soldered. The binders consist of half a dozen turns of No. 24 tinned copper wire, tightly wound round the two grooves, turned in the armature core, and soldered. A thin layer of tape or mica should be placed under them first to protect the windings.

When finished give the whole armature several

coats of shellac varnish, and bake it at a gentle heat for some hours.

The machine is now ready to put together.

A winding diagram showing the connections is given in Fig. 119.

When completed the machine can be tested as a motor by connecting it to an accumulator of 4 volts

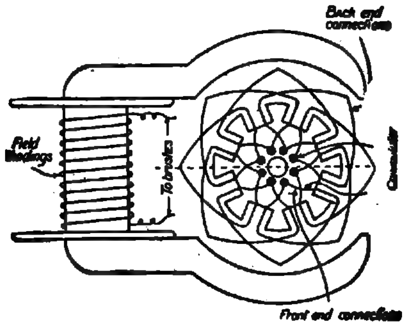


Fig. 119.—Winding Diagram

to 10 volts and 20 ampere-hours capacity. Should it not run, move the brushes round a little way in one direction or another. Should it run in the contrary direction to that required, reverse the connections of the field windings to the brushes.

CHAPTER X

Winding Data

THE voltage obtainable from a small dynamo is roughly determined by the length of insulated copper wire coiled on its armature. The diameter of the wire governs the length that can be got on an armature of a given size.

In small dynamos, each yard of active wire on the armature will give about 1 volt (all other conditions being favourable) when moving at a circumferential velocity of 1,250 ft. per minute.

This last statement requires some explanation to make it clear. Active wire is that portion of each coil of wire which is employed in cutting through the lines of magnetic force given out by the field-magnets.

On a drum armature all the wire except the parts of the coils over the ends of the drum is active wire.

The dead wire on a shuttle armature should not exceed one-third of the total length employed, and to secure this proportion the length of the armature core must not be less than three times its diameter. In a ring armature the relative quantities of dead and active wire will depend upon the thickness of the ring, but it must be remembered that the wire which passes inside the ring is also dead wire.

The circumferential velocity of the wire coils may

be taken to be the same as that of the periphery of the armature on which they are wound. As the circumference of a ring or drum is 3·14 times its diameter, multiply the diameter of the armature in inches by 3·14 to ascertain its circumference in inches. This done, find how many times it will have to turn to cover a foot length, and multiply this number by 1,250 to find how many revolutions the armature must make in a minute to produce one volt from each active yard of wire in its coils. It will thus be seen that the voltage is conditional on the speed of the armature.

It is also conditional upon the strength of the magnetic field, which must be at its maximum to get the best result.

Carrying capacity in amperes is calculated at about 2,000 amperes per square inch. The safe carrying capacity of the wire is the maximum current it will carry without heating to such an extent as to affect the insulation seriously.

The resistances given in the following table are for 100 per cent. conductivity copper at a temperature about 65° F.

Under the heading "No. of turns per inch" will be seen three divisions—A, B and C. Of these B and C refer to wires which, in the small sizes, have special thin coverings of silk and cotton respectively. Under A the insulation is reckoned at the rate of 12 mils = $\frac{3}{250}$ in. of double cotton in sizes below No. 16. Above this size the average covering is about 14 mils, varying from 10 to 20 mils, however.

The output of a dynamo—that is, its electrical power—is generally calculated in watts. This is

No. S.W.G.	Diam. Inches.	Sectional Area. Square Inches.	Weight per 1,000 Yards in Lbs.	No. of Turns per Inch.			Current in Amperes.			Resistance in Ohms per 1,000 Yards.
				A.	B.	C.	At 1,000 Amperes per Square Inch.	At 1,500 Amperes per Square Inch.	At 2,000 Amperes per Square Inch.	
22	·028	·0006	7	24	28	26	·6	·9	1·2	40·78
20	·036	·0010	12	20	26	23	·1	1·5	2	24·11
19	·040	·0012	15	18	23	20	1·2	1·8	2·4	19·98
18	·048	·0018	21	16	20	17	1·8	2·7	3·6	13·88
17	·056	·0024	28	14	17	15	2·4	3·6	4·8	10·2
16	·064	·0032	37	12·8	15	14	3·2	4·8	6·4	7·6
15	·072	·0040	47	11·5	13	12	4	6	8	6·11
14	·080	·0050	57	10·5	11	10	5	7·5	10	5
13	·092	·0066	76	9·5	10	9	6·6	9·9	13·2	3·78
12	·104	·0085	98	8·5	9	8	8·5	12·75	17	2·95
11	·116	·0105	122	7·5	7	6	10·5	15·75	21	2·36
10	·128	·0128	148	7	6	6	12·8	19·2	25·6	1·95
9	·144	·0162	188	6	5	5	16·2	24·3	32·4	1·55
8	·160	·0201	245	5·7	4	4	20·1	30·15	40·2	1·26

obtained by multiplying the total voltage by the amperes. But as this method of stating a dynamo's output admits of uncertain interpretation, it is best to specify the volts and amperes separately.

In a series machine the field-magnet coils are connected in series with the outer circuit. The magnetism in the fields, therefore, varies inversely as the resistance of the circuit, being less when the resistance is high than when it is low.

In a shunt-wound machine the field-magnet coils are connected in a shunt with the outer circuit; there are, therefore, two paths open to the armature current —one through the field-magnet coils, and the other through the outer circuit. If the resistance in the outer circuit is lower than that of the field-magnet coils, more current goes by way of the outer circuit than goes round the coils, but when the resistance of the outer circuit is increased, more current goes by way of the coils, and this raises the magnetic intensity of the fields. The effect of this is to raise the voltage of the current, and enable it to overcome the extra resistance.

In a compound-wound machine the field-magnet coils are partly of thick wire connected in series with the armature and outer circuit, while a small wire of high resistance is connected in shunt. This form of machine may be made to give almost a constant potential difference at the terminals.

Each style of winding has its own peculiar advantages, adapting it to the kind of work to be done by the machine. A shunt-wound dynamo is self-regulating to a certain extent, for as the lamps are switched off the resistance in the outer or lamp circuit becomes greater, and more current is shunted through the field coils, thereby generating a higher voltage to overcome the increased resistance. A compound-wound dynamo is self-regulating to a still greater extent.

It is almost impossible to determine exactly the output of small machines; apart from the variations

from theoretical rules, others are likely to crop up through differences in the qualities of iron employed, hardness of wire, irregular or loose winding, insulation, connections, size, form and make of commutator, and position and pressure of brushes, etc.

Properly designed castings for the carcass of the dynamo usually have ample space allowed for winding sufficient wire to suit the electrical output of the machine. If the carcass of the machine has to be forged or cast, and the rings or punchings for the armature made to order, proper space must be allowed for the wire. By referring to the table given on page 126, the space likely to be occupied by the wire will be found under the heading "No. of turns per inch"; that is, so many turns of wire of a given gauge will lie side by side in 1 in. of space. The channel in a shuttle armature must be large enough to take the required wire without bulging beyond the cheeks. In the case of a plain drum or ring armature the space between the outer edge of the ring or drum armature and the sides of the tunnel in which it is to work should be sufficient to leave $\frac{1}{16}$ in. between the wire and the sides after three layers of the wire have been wound on. One layer is theoretically the best, but three layers are admissible.

The length of the field-magnet cores for a shuttle armature dynamo may be about two or three times their diameter, and provision should be made to admit of enough wire to increase the diameter of the core from two and a half to three times. The space to be occupied by the wire may be ascertained by estimating

its length and weight or length per pound, noting how many turns to the inch it will run. Estimate the probable diameter of the wound core, and find the mean between this and the bare core, then multiply this by the factor 3·14, and so ascertain the number of turns and the space likely to be occupied by the wire.

Heavy yokes and pole-pieces are always admissible, because dynamos work best when the iron in them is in excess of that needed to maintain magnetic saturation. It is also advisable to have a larger carcass than will be actually needed to furnish the required output, since machines may always be safely worked to light fewer lamps than they were designed for, but it is not safe to work them at a higher speed to procure a larger output.

Before the plan for winding the armature can be drawn up, the resistance of the outer circuit—namely, the work to be done by the machine—must be first ascertained. If this resistance is too low, a shunt machine will fail to supply the required current and a series machine will burn its coils. If too high, no current will be obtained from a series machine, and that from a shunt machine will be diminished. In large machines, carefully wound, an efficiency of 1 volt per foot of effective wire on the armature moving at a circumferential velocity of 1,250 feet per minute has been attained, but, as has been stated, 1 volt per yard is what may be expected from small machines.

Although the voltage of a machine may be increased by increasing the speed of its armature, it

is not always safe to do so, because an increased voltage will send more current round the field-magnet coils, and this may dangerously heat them. In a series machine all the current passing through the outer circuit also traverses the field-magnet coils. In a compound machine the bulk of all its current passes through the series coils and only a fraction of it through the shunt coils. In a shunt machine only a fraction of the current passes through the field-magnet coils. Consequently the fields of the series machine are not magnetised when the outer circuit is open, and the fields of the shunt machine are then most highly magnetised.

When a machine is run at a higher speed the brushes should be given a more forward lead, to compensate for increased distortion of the field.

The wires on dynamos should be protected from damp, etc., by some insulating and damp-proof coating. Shellac varnish is one of the best for the purpose. This is made by digesting shellac in methylated spirit, by keeping it in a stoppered glass jar in a warm place for twelve hours. Green or red sealing-wax digested in warm methylated spirit is also used as an insulating varnish.

Few persons can get the calculated amount of wire on an armature, although perhaps in the design a full allowance has been made for slack winding. To take an armature in one hand and let the wire run through the fingers of the other, drawing it more or less tight, winding as one would wind up a ball of string, sometimes working evenly, sometimes not, will

not do. To wind an armature properly, especially if of either the drum or ring types, is work for two people. Even a shuttle armature should not be attempted by one person unless he is an experienced winder, and even then he will wish he had three hands.

After the wire has been properly paraffin-waxed and drained it should be wound on as tight as possible, without, of course, breaking it. Any wire that is not perfectly straight should be carefully straightened in order that it will lie in its proper place. Every wire should be made to go as near to its neighbour as possible. It will be seen that winding an armature properly is no light work.

Cheap wire is very bad, for two reasons—one is that the wire itself has a comparatively low percentage of copper, and wire should not be used that has less than 97 per cent., as it gives the armature a needlessly high resistance. The other reason is that cheap wire has bad, thick cotton for its covering, and consequently occupies space wastefully.

Another source of trouble is thick, clumsy taping. There should be just enough to ensure perfect insulation, and no more.

CHAPTER XI

Faults and their Remedies

To localise the faults common to dynamos the apparatus required will comprise a battery of three or four cells of a strong and constant type, a galvanometer, or current detector such as those used by electric-bell fitters, and a magnetised needle or a pocket compass. For purposes of repair, a soldering-iron, some soft solder, some resin, a pair of stout pliers, a screwdriver, small spanners to fit the nuts on the machine, and some soft cotton or tape, or both, well soaked in shellac varnish. About 2 ft. of No. 18 or No. 20 S.W.G. wire will serve to connect the battery with the galvanometer and the machine. A steel darning-needle, magnetised by rubbing it on a permanent magnet, and suspended by a piece of cotton to hang horizontally, will serve as a substitute for a pocket compass. With this apparatus the following faults may be localised.

If the cores of the magnets are not magnetised no current will be generated in the armature coil. If one of the field magnet coils of an overtype or undertype machine is wound in the wrong direction, both pole-pieces may have a like magnetism, and the same negative result will be obtained. One pole-

piece must have an opposite polarity to the other. The compass needle being held near the pole-pieces of an ordinary two-pole machine, one of them should attract the north pole of the needle, and the other repel it. The machine should be tested in this way whilst the armature is at rest, and also when it is running. If the coils are wrongly connected there may be a similar result. If the compass needle does not indicate any magnetism, or only a feeble magnetism, it may be assumed that the pole-pieces are not magnetised.

A series-wound dynamo employed in depositing metals from their solutions, or in charging accumulators, is liable to have its poles reversed by a back current from the plating-vat or the accumulator cells. For this reason series dynamos are not suitable for such work. The polarity of the core is also reversed when current is sent through its coils from a battery, or another dynamo, to run the machine as an electric motor. Compound-wound machines are also liable to a reversal of their magnetism from a similar cause, owing to a high reverse current passing through the series coils. A shunt-wound machine can only be reversed by such means when its field-magnet coils are wrongly connected to a battery, therefore a shunt-wound machine should always be used for charging accumulators and for electro-depositing work. This altered polarity of the field-magnets may be detected by the compass needle being held to them; the original magnetism should be restored by passing a current round the fields in the right direction.

Magnetism neutralised, which may also be named short-circuiting the magnetic poles, occurs when the poles are bridged by a mass of iron, as when an undertype field is bolted direct to an iron bedplate, or an overtype field is bridged by an iron plate secured to the pole-pieces. When an air space is left between the polar extremities of a horseshoe magnet, the magnetic lines of force may be supposed to stretch across from one pole-piece to the other, and are then in a position to pass through the armature coils. But when a piece of iron bridges these polar extremities, the greater number of the magnetic lines pass by way of this bridge, and so are diverted through the armature from their useful path, and as there are, therefore, few or no lines of force passing through the armature, there will be a very faint current from the machine, or none at all.

The guard over the armature space of an overtype dynamo should be of zinc or gunmetal; if it is necessary to have an iron bedplate for an undertype dynamo, brackets of gunmetal or of zinc should be interposed between the magnet poles and the iron of the bedplate.

If the machine does not give a current, or the desired effect, though the magnetic properties of the field have been tested as directed and found all right, leakage or short-circuiting of the coils may be suspected. To detect this we must employ a battery or galvanometer, as before explained.

Leakage most frequently takes place between the wire of the coils and the iron of the field-magnets or

the armature. Perhaps the rough corners on the castings have not been made smooth. Perhaps the iron has not been properly insulated; and the wire has been pulled tight over rough or unprotected parts, and the insulation has been cut through, thus bringing bare copper into contact with bare iron. As a consequence, the current takes a short cut by way of the iron instead of going through all the coil of wire, and the result is seen in a diminished output from the machine.

The following is a rough-and-ready means frequently adopted for discovering this fault. Disconnect the ends of the field-magnet coils from their terminals, and connect one end of the coils to one terminal of the battery. Then take a long exploring wire and connect to the opposite terminal of the battery, and with the free end of this scrape the ironwork and metalwork of the machine at several points. If any bare part of the wire coil is touching the bare iron of the machine a bright spark will be seen to flash from the part of the machine touched with the exploring wire. By disconnecting the two coils from each other and testing each separately, the faulty one may be discovered.

The armature coils may be tested in a similar manner—in fact, they must be tested for leakage as well as those of the fields. It is advisable, however, in both cases, to place the galvanometer in circuit by connecting the battery to it, and then to connect the exploring wire to the galvanometer. If the needle moves it shows that there is a leakage, however small

or large this may be, but the rough test will only reveal a bad leakage.

Leakage may occur between adjacent turns or layers of wire in the same coil, and is due to the stripping off of the insulation, from some such cause as hammering the coils to get them in their proper places, or from pulling them too tight. If a machine is overdriven, or if a series machine is short-circuited, the insulating covering may get burnt off, and thus the coils become short-circuited.

This fault can only be discovered by means of the galvanometer in circuit with the battery. Each coil must be placed in circuit separately, the deflections of the galvanometer needle noted, and these compared.

Equal lengths of wire should have equal resistances, and this should be indicated by equal deflections of the galvanometer needle. If the needle swings over much farther when one coil is in circuit than when a similar coil of the same length is tested, it is probable that that coil is short-circuited somewhere, because it offers a less resistance than the perfect coil. Each coil of the armature should be unsoldered from the commutator bars and tested separately in comparison with the others. All faulty coils must be unwound and the fault repaired by winding insulating tape over the bare spot.

Leakage sometimes occurs between the commutator bars and the spindle, or between the sections of the commutator itself, or between the brush-holders and other parts of the machine. Any of these

leakages may be detected by the galvanometer and one or more cells of the battery.

The commutator bars may be accidentally placed in contact with the spindle by using long screws. To detect this fault attach one battery wire to the spindle and the other to the galvanometer, then touch each bar with the free wire from the galvanometer and watch the indications of the needle. If the needle moves when a bar is touched that bar is in contact with the spindle. Any faulty screw must be withdrawn, and a shorter one used. If the bars are accidentally connected by metal dust, or by expansion of the sections whilst heated, this fault may be detected by placing one wire from the battery on one bar and the wire from the galvanometer on the next bar. The coils must be disconnected from the bars whilst this is being done.

Sometimes the brush holders are not insulated from the machine. This fault may be detected by testing each separately with the body of the machine in circuit, and then testing the two together. If all is right, no current should pass between them and the machine or between the two holders when the brushes are off, and they are disconnected from the outer circuit. Perfect insulation at these points is of the greatest importance.

A machine tested at all points indicated above and found all right, or the detected faults put right, and yet that will not give satisfaction, may have a fault in the brushes. All brushes, in any type of machine should be held in suitable brush holders fixed to an

insulated rocker, or in insulated sleeves attached to such a rocker. Fixed brushes on standards, or on blocks attached to the machine, give much trouble, since they can only be adjusted by the exercise of much time and patience, and even then cannot be trusted to remain right for any length of time.

The most inexpensive and efficient material for brushes in small dynamos is copper gauze, cut into strips of suitable width and length, and formed into pads by soldering the strips together at the ends to go in the brush holders. As these pads have very little elasticity in them, it is advisable to back them with a strip of spring steel, German silver, or brass, so as to ensure enough pressure to keep them in good contact with the commutator. Machines frequently fail because of having hard brass brushes, which press unevenly on the commutator, or get thrown out of contact when the machine is driven at a high speed. Pads of copper gauze bear and wear more evenly than springs of hard brass.

When these pads are fixed to a rocker they may be easily adjusted to any position. The theoretically correct position for the brushes is for their ends to bear on the commutator bars opposite the centre of the open spaces between the field-magnets. In practice, however, the position is always in advance of this, because the armature current distorts the lines of force in the magnetic field. This forward position or lead of the brushes must be found by experiment, because it varies with the type and speed of every machine. As a rule, the highest speed

demands the most forward lead. If the machine is connected to a suitable ammeter when driven at the required speed, and the brushes are moved until the best effects are noted by the deflection of the needle this will be the best position for the brushes.

The machine may run all right, and give a fairly good current for a short time, but there may be much sparking at the brushes, burning them away and burning pits in the commutator. This shows defective construction or bad adjustment of the brushes.

The likely faults in construction are: Coils of a varying length and resistance on the armature, insufficient resistance in the field-magnet coils, or leakage between the armature coils and the carcass of the machine. This last defect may be found by examining the armature coils. Perhaps these touch the iron occasionally, and rub off the insulating coating. This may be due to too much end-shake of the armature spindle, to a worn bearing, or to a loose bearing allowing the armature to wobble.

A small washer on the spindle will correct too much end play, tightening the nuts will remedy a loose bearing, but a worn bearing should be rebushed. If leakage occurs the worn spot should be coated with varnish worked in well between the folds of the wire. Sparking may indicate that too much work is being thrown on the machine. Sparking due to bad adjustment of the brushes can be cured by altering their lead.

A broken armature wire can be mended as follows:

If it is outside the winding, bare and clean the two ends, twist and solder them together, then paint the joint over with sealing-wax varnish. If it is in the winding, bare and bevel the two ends, tin the bevels, and sweat the joint together, then work up to as near the size of the wire itself as possible, relap the joint with silk, and coat with varnish.

Some of the best designed and constructed machines will get too warm after a long run on heavy work. The passage of the electric current through the wire coils will always warm them more or less, and much of this rise of temperature is unavoidable. When the temperature rises considerably, as when the field-magnet coils feel quite hot if touched by the hand, there is always a serious loss in heating the wires. The main cause of this excessive heating is the employment of wires too small to carry the current properly, or in other words, the machine is required to do more work than it is properly capable of doing. The remedy here is clear enough. But sometimes the heating of a machine is due to defective construction, or it may be due to leakage.

Solid iron armatures may get unbearably hot in a short time, because of cross or eddy currents circulating in the mass of iron from end to end of the armature. In the case of a laminated armature, as the laminations are separated from each other by an insulating substance (even a thin coat of varnish or film of oxide is sufficient), these currents are broken up, and cannot travel from end to end. Machines with solid iron armatures will get hot enough to melt

the soft solder connections at the commutator and distort the commutator sections.

In series and compound machines leakage across the brushes will also heat the coils injuriously. Short-circuiting a series machine may seriously damage it by charring the insulating covering of the wires.

These are the most common ailments of small dynamos. Others there are, but it will often be found that these are due to faulty workmanship:

The amateur seldom succeeds in securing good insulation in his first attempts; his coils do not lie evenly enough to please him with the first attempt it may be, or they slip and need rewinding several times. The cotton covering on the wires is very apt to get damaged then from too much handling, and finally, when all the sections are wound, most of the crossings where the end windings are situated will probably "leak" one to another, if not to the iron core as well.

The trouble may be helped by endeavouring to crowd too much wire into the slots, and dealing afterwards with refractory conductors that project with a hammer!

The use of the hammer or mallet on armature wires should never be permitted, the wires being laid in their places under finger pressure only, or pressed down gently (not hammered) with a piece of vulcanised fibre or hardwood.

Presuming the armature winding is free from faults and rightly connected, the commutator is the

next place for examination; defective insulation between adjacent segments, or between sleeve and segments will often put an armature, otherwise in good order, out of running.

The commutator must be truly cylindrical, and mounted to run quite true on the shaft; if eccentric it may throw the brushes off at a high speed and render it impossible to collect the current sparklessly, if at all. The brush holders themselves should be inspected and tested to see that they do not leak to the frame of the machine; and lastly, the terminals overhauled with the same object.

When the machine has been put in satisfactory order it is best if possible to connect the terminals to a battery of accumulators, giving approximately the same voltage as the dynamo output is supposed to be, protecting the cells by a fuse to avoid damaging anything by excessive current. The machine should then run as a motor, and the brushes can be adjusted until the position of least sparking is found.

Should the machine run against the brushes or in the wrong direction, disconnect the field windings where attached to the main terminals (or brushes), and change over the ends. This will reverse the direction of rotation.

When used as a dynamo the machine will run in just the same direction as it did as a motor, but the position of the brushes may want altering slightly to secure the best position for maximum output and minimum sparking.

A motor requires "backward lead" given to the

brushes, and a dynamo "forward lead," the terms backward and forward being expressed relatively to the direction of rotation.

The general attention which a dynamo requires is similar to that needed by all high-speed machines. Keep all bearings and wearing parts clean and properly oiled. See that the driving belt does not slip but yet is without undue tightness. It must also be remembered that in addition to the bearings the commutator and brushes are the wearing parts of the machine. The brushes must be adjusted to the proper angle, as before explained. Sparking wears away brushes and commutator very fast, and thus will demand frequent adjustment of the brushes to keep them bearing on the best part of the commutator. When the brushes have cut grooves in the commutator it is necessary to re-true the furrowed part, and sometimes to put in a new segment.

CHAPTER XII

Various Dynamos and Motors

It frequently so happens that the amateur becomes possessed of some portion of a dynamo, such as a field-magnet, armature, etc., or perhaps a set of castings, which he is desirous of making up into a complete machine.

It is manifestly impossible in a book of this size to give particulars of every size and class of machine, but among those included in the following pages the reader will probably find a design more or less applicable to his own needs. No attempt has been made to give constructional details, but the information contained in the earlier chapters will be a sufficient guide.

Light 8-volt Motor.—To secure the greatest power with the minimum weight, both the fields and armature must be built of special wrought-iron stampings, while all castings, such as end brackets, must be in aluminium alloy. Ball bearings are advisable, and d.s.c. copper wire used for the windings throughout.

The dimensions of the field-magnet armature and system are given in the illustrations, Figs. 120 and 121. The field is built up of stampings in No. 20

gauge iron, and the armature in No. 24 gauge, to a depth of 1¼ in. The aluminium end brackets are bolted to the fields by $\frac{3}{32}$-in. steel studs and nuts, carrying the brush holders at one end, and the main terminals at the other.

The centre portion is recessed for a ¼-in. Hoffmann S-type ball journal bearing.

The armature is of the eight-slot laminated drum

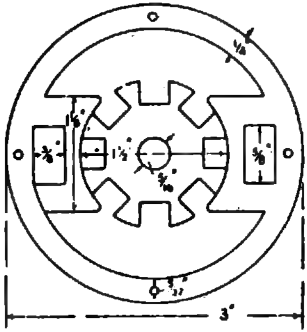


Fig. 120

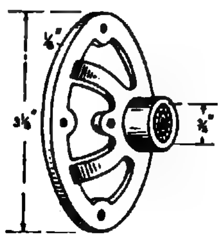


Fig. 121

Figs. 120 and 121.—Details of Light 8-volt Motor

type, and a disc commutator with eight segments fitted.

For an 8-volt circuit the motor will require winding with 3½ oz. of No. 24 on the armature, and 7 oz. of No. 20 on the fields, connected in series.

40-watt Dynamo with Wrought-iron Magnets.—A dynamo with field-magnets made out of wrought-iron bar is shown in the dimensioned drawings (Figs. 122 and 123), and this should present no

difficulty in making up. The field-magnet is bent to shape from 2-in. by ⅜-in. wrought-iron bar, and especial care is necessary to ensure that the bore of the field is as accurate and uniform as possible.

The armature is the tripolar type wound with No. 22 s.w.g.d.c.c. copper wire.

The bearings may be cut from 1-in. by ½-in. brass, with neatly squared ends, and oiling holes in the top.

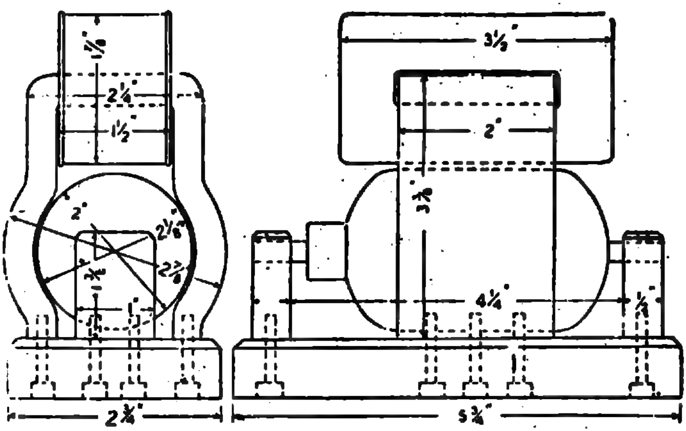


Fig. 122 Fig. 123

Figs. 122 and 123.—Built-fields Undertype Dynamo

The magnet and bearings must be drilled and tapped for ⅛ in. Whitworth fixing screws.

If the field coil is wound with about 2 lb. of No. 22 s.w.g. copper wire, and connected in shunt with the armature, an output of 4 amperes at 10 volts may be expected from the machine.

When complete, mount the dynamo on a polished or varnished hardwood base. using cheese-head iron

or brass screws, the base being drilled and countersunk to receive them.

Washers must be used in the countersunk holes to make a good job of the fixing.

Built-fields Overtype Dynamo.—The accompanying illustration shows a field-magnet built up in five pieces (Fig. 124). The dimensions shown are for a machine of 100 watts, but, of course, such a machine could be constructed in a smaller size.

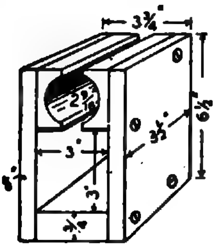


Fig. 124.—Built Field-magnet

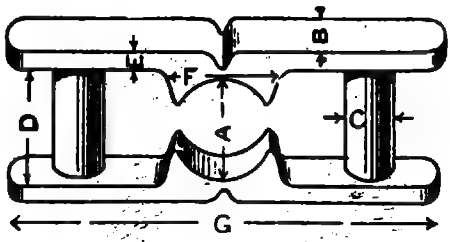


Fig. 125.—Field-magnet for Low-speed Dynamo

The armature is 2½ in. in diameter and 3½ in. long, with 12 slots, and wound with 12 oz. of No. 22 d.c.c. copper wire.

The field winding may consist of 4 lb. (2 lb. on each limb) of No. 22 wire, connected in shunt, and the speed will be approximately 2,000 revolutions per minute for an output of 20 volts 5 amperes.

Low-speed 20-watt Dynamo.—There are hardly any limits to the variation in speed for a given output to be secured by careful designing; but it must be remembered that the lower the speed the larger the machine must be, and cost goes in proportion to size.

A moderate speed for an output of 20 watts would be 2,500 revolutions per minute, and this can be secured by making the field-magnet casting of the following dimensions: A (see Fig. 125) = 2 in., B = 1½ in., C = 1 in., D = 2¼ in., E = ⅝ in., F = 2 in., G = 8 in.

Wind the armature, an eight-slot drum or ring, with 3½ oz. of No. 24, and the fields with 5 oz. on each limb of No. 22, connected in shunt.

6-volt Tripolar-armature Motor or Dynamo.—The leading dimensions of the field-magnets are shown in Figs. 126 and 127.

The armature is 1¾ in. in diameter, and is 2 in. long parallel to the shaft.

Cast iron can, of course, be used for the armature, but better results may be expected if stampings are obtained of the shape and to the dimensions shown, and are built up on a $\frac{3}{16}$-in. diameter spindle to a total length of 2 in.

The field-magnet is, of course, to be made of good, soft cast iron, the pole-faces being bored out to 1⅞-in. diameter, allowing $\frac{1}{16}$ in. air gap between the armature and pole-faces.

For the motor to run at 2,000 revolutions per minute, taking current at 6 volts, both the field coil and armature can be wound with No. 20 S.W.G. copper wire, single-cotton-covered. From 200 to 220 turns can be wound on the armature, or say 70 turns per T-pole: this will take about ½ lb. of wire.

On the field coil wind eighteen layers of the same wire; this requires approximately 1½ lb. of wire, and

when the coil is connected across 6 volts it will pass 2 amperes.

If the machine is run as a dynamo, 6 volts 5

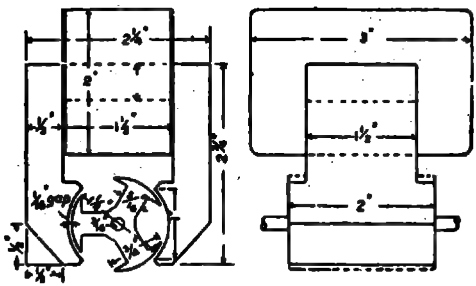


Fig. 126 Fig. 127

Figs. 126 and 127.—Tripolar-armature Motor

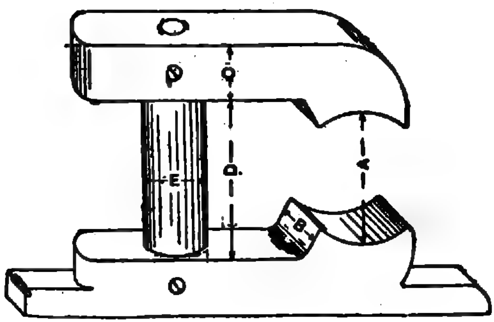


Fig. 128.—Built-up Simplex Fields

amperes will be obtainable from the armature when running at about 2,500 revolutions, and if 2 amperes are allowed to flow in the field coil, 3 amperes will be available for the outside circuit.

Built-up Simplex Fields.—The line drawing (see Fig. 128) shows the general appearance of a field-magnet built up of three pieces, the dimensions being as follows: A, 2 1/32 in.; B, 2½ in.; C, 1 in.; D, 2½ in.; E, 1¼ in. The magnet is built up of three parts, the core E of best wrought iron, and the top and bottom yokes of annealed grey cast iron. The core D has a pin turned on each end, about 1⅜ in. in diameter, and is well fitted into the castings, and kept in position by set-screws as shown.

1/16-H.P. Ironclad Motor.—The illustration (Fig. 129) shows the dimensions of the carcass, which is to be of well-annealed grey cast iron, and also of the armature which is a laminated slotted drum.

The shaft is of mild steel ½ in. in the largest diameter, ⅜ in. through the armature core, 5/16 in. through back bearing and commutator sleeve, ¼ in. through the front bearing and pulley.

The commutator has eight sections of hard drawn copper insulated with mica, and mounted on a brass sleeve; diameter 1¼ in., length ⅝ in.

The pulley with V-groove is 1 in. in diameter and ⅜ in. wide.

For 10 volts wind the armature with 3 oz. of No. 24 d.c.c. copper wire, and the fields with 12 oz. of No. 22 connected in shunt; or if a series motor is desired use the same armature winding, but No. 18 on the fields.

Continuous-current Permanent-magnet Dynamo.—The dimensions of this are as follow, but there is no reason why they should not be modified to suit a

magnet which may be in the possession of the reader. Tripolar armature 2 in. by 1½ in. long, and a permanent steel magnet 1½ in. by ¼ in. thick by about 5 in. high, bent into horseshoe shape with parallel sides.

First make two cast-iron pole tips to fit against

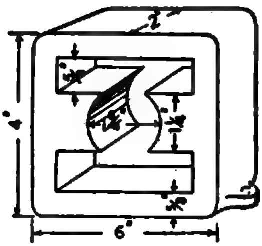


Fig. 129.—Ironclad Field-magnet

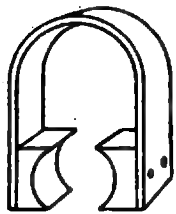


Fig. 130

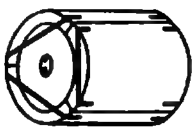


Fig. 131

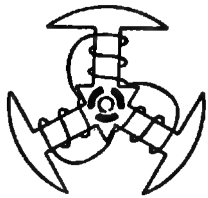


Fig. 132

Figs. 130, 131 and 132.—Details of Permanent-magnet Dynamo

the inner side of the magnet limbs, and shaped to the same curve as the armature.

They are fixed to the bottom ends of the steel magnet with a couple of screws, and are made to embrace about one-third of the circumference of the armature on each side (see Fig. 130).

If the armature is a solid casting it can be bored

centrally, and a piece of silver steel driven in to form the shaft. If stampings are used, rivet them together over a piece of brass tube, and then drive the steel shaft through this.

A simple three-part commutator can be built up from a short piece of stout brass tube driven on to a fibre bush. Three saw cuts are made at the end, a little way in (see Fig. 131), and pieces of sheet brass soldered in. Afterwards the tube is divided lengthwise into three segments with a fine hack saw, bored and driven on the shaft.

The magnets can be held on to a hardwood base by screws tapped into the cast-iron pole-pieces from below, and separate bearings can be similarly fixed in appropriate positions, being made either of stout brass turned up into an angle, or from small brass castings.

Two strips of No. 26 gauge spring brass $\frac{3}{8}$ in. or $\frac{5}{16}$ in. wide, faced with a couple of layers of copper gauze, will answer as brushes, being screwed down to the wood base by terminals which also serve for connecting to outside wires.

The method of winding and connecting the armature is shown in Fig. 132, and the wire recommended is No. 24 double silk covered, of which about 3 oz. will be required.

This machine will give enough current to light a 10-volt 10-candle-power Osram lamp.

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